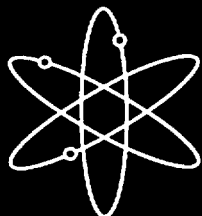
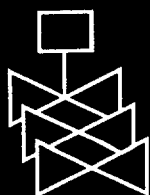


Component Performance Study—Air-Operated Valves, 1987–1998



Commercial Power Reactors



U.S. Nuclear Regulatory Commission
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Component Performance Study—Air-Operated Valves, 1987–1998

Commercial Power Reactors

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Prepared by
J.R. Houghton

**Division of Risk Analysis and Applications
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Washington, DC 20555-0001**



ABSTRACT

This report documents an analysis of the performance of safety-related air-operated valve assemblies (valve body and pneumatic operator subcomponents) used in the pressurized water reactor (PWR) and in the boiling water reactor (BWR) risk-important systems in U.S. commercial power reactor plants.

Both a risk-based analysis of operating data and an engineering analysis of trends and patterns were performed to provide insights into the performance of air-operated valve components on an industry basis and comparison of results with data used by plant-specific probabilistic risk assessments. The data used in this report was from the 1987–1995 period for engineering analysis of selected risk important systems. Failure probability estimates used combined engineered safety features (1987–1998) and surveillance test data (1987–1995).

CONTENTS

ABSTRACT	iii
EXECUTIVE SUMMARY	vii
FOREWORD	xiii
ACKNOWLEDGMENTS	xv
ACRONYMS	xvi
1. INTRODUCTION	1
1.1 Purpose	1
1.2 Background	1
1.3 Overall Report Structure	2
2. SCOPE OF STUDY	3
2.1 Risk-Important Systems and Components	3
2.2 AOV Assembly Description and Boundaries	4
2.3 Data Collection	4
2.4 Operational Data Analysis	7
3. Risk-Based Analysis	9
3.1 Calculation Results	9
3.2 Common-Cause Failure Events	11
3.3 Comparison With IPEs and Other Sources	12
4. ENGINEERING ANALYSES	14
4.1 Failure Trend Analysis	14
4.2 Component Trends in Time	16
4.3 Failure Characteristics and Their Causes	20
4.4 Related Issues	23
5. SUMMARY OF RESULTS	25
5.1 Failure Probabilities	25
5.2 Engineering Insights	26
6. REFERENCES	27

CONTENTS (CONTINUED)

FIGURES

ES-1	PWR AFW System AOV Probability of Failure on Demand — Comparison With IPE Values	viii
ES-2	PWR RHR System AOV Probability of Failure on Demand — Comparison With IPE Values	ix
ES-3	PWR CVCS System AOV Probability of Failure on Demand — Comparison With IPE Values	ix
ES-4	PWR AOV Failure Trend	x
ES-5	PWR AOV Subcomponent Failure Apportionment	xi
ES-6	PWR AOV Assembly Failure Causes	xi
1	NPRDS Database AOV Failures	5
2	SCSS Database AOV Failures	5
3	PWR AFW System AOV Probability of Failure on Demand — Comparison With Values Used in IPEs	13
4	PWR RHR System AOV Probability of Failure on Demand — Comparison With Values Used in IPEs	13
5	PWR CVCS System AOV Probability of Failure on Demand — Comparison With Values Used in IPEs	14
6	PWR AOV Failure Trend	15
7	PWR AOV Component Trends in Time	19
8	PWR AOV Subcomponent and Subcomponent Parts Failure Apportionment .	21
9	PWR AOV Failure Causes	22

TABLES

ES-A	AOV Probability of Failure on Demand	vii
ES-B	AOV Standby Failure Rate	viii
F-1	Summary of Risk-Important Information and Engineering Analysis for AOVs .	xiv
A	AOV Probability of Failure on Demand (1987–1998)	10
B	AOV Standby Failure Rate (1987–1998)	11
C	AOV Failures in the CCF Database (1987–1995)	12
D	NRC Generic Letters (GLs) and Information Notices (INs) Concerning AOV Assemblies (1987–1998)	23

APPENDICES

I	AOV Assembly — Failure Probabilities
II	AOV Assembly — Component Trends in Time
III	AOV Assembly — Engineering Insights
IV	AOV Assemblies — Data Source Inputs for Reported Failures and Estimated Demands

EXECUTIVE SUMMARY

This report provides the performance evaluation based on industry experience during the 1987 through 1998 period for air-operated valves (AOVs) in the pressurized water reactor (PWR) and in the boiling water reactor (BWR) risk-important (RI) systems. The main steam isolation valves (MSIVs) and power-operated relief valves (PORVs) are excluded from this study because their design and operational features are different than the typical piston/diaphragm AOVs in this study. The objectives of component performance are (1) to determine the reliability of risk important components and compare the results with estimates in probabilistic risk assessments (PRAs) and individual plant examinations (IPEs) and (2) to review the operational data from an engineering perspective to determine trends and patterns and gain insights into component performance.

AOV failure and estimated demand data was obtained from two databases. The Nuclear Plant Reliability Data System (NPRDS) provided component failures and surveillance test frequencies for the 1987–1995 period. The Sequence Coding and Search System (SCSS) provided Engineered Safety Features (ESF) failure and demand data for the 1987–1998 period and some surveillance test failure data for the 1987–1995 period reported in Licensee Event Reports (LERs).

For the PWR and BWR RI systems, the AOV estimated probability of failure on demand distributions were consistent with the generic value range from NUREG/CR-4550 (used as an input to NUREG-1150), although the PWR RHR system mean value ($5.2\text{E-}4$) is about a factor of 4 lower than the generic mean value ($2\text{E-}3$). Table ES-A lists the probability of failure on demand estimates developed for the RI systems selected for this study and the NUREG/CR-4550 values. For AOVs risk important systems, there was no statistically significant yearly trend for probability of failure on demand. Table ES-B gives the standby failure rates for each system.

TABLE ES-A
AOV PROBABILITY OF FAILURE ON DEMAND

	LOWER BOUND	MEAN	UPPER BOUND
NUREG/CR-4550	$5.4\text{E-}4$	$2\text{E-}3$	$4.8\text{E-}3$
PWR RI SYSTEMS			
auxiliary feedwater (AFW)	$4.6\text{E-}6$	$1.8\text{E-}3$	$6.9\text{E-}3$
high pressure injection (HPI)	$4.8\text{E-}6$	$1.2\text{E-}3$	$4.7\text{E-}3$
residual heat removal (RHR)	$6.1\text{E-}5$	$5.2\text{E-}4$	$1.3\text{E-}3$
chemical and volume control system (CVCS)	$3.5\text{E-}7$	$3.4\text{E-}3$	$1.5\text{E-}2$
component cooling water (CCW)	$6.7\text{E-}5$	$5.8\text{E-}3$	$2.1\text{E-}2$
BWR RI SYSTEMS			
reactor core isolation cooling (RCIC)	$3.5\text{E-}4$	$3.0\text{E-}3$	$7.7\text{E-}3$
high pressure coolant injection (HPCI)	$4.3\text{E-}4$	$3.6\text{E-}3$	$9.5\text{E-}3$
low pressure core spray (LPCS)	$2.9\text{E-}15$	$2.1\text{E-}3$	$1.2\text{E-}2$

TABLE ES-B
AOV STANDBY FAILURE RATE

	LOWER BOUND(λ_l)	MEAN(λ)	UPPER BOUND(λ_u)
PWR RI SYSTEMS			
AFW	4.8E-7/hour	8.2E-7/hour	1.3E-6/hour
RHR	6.9E-9/hour	1.3E-7/hour	6.4E-7/hour
CVCS	4.0E-7/hour	6.0E-7/hour	8.5E-7/hour
CCW	1.3E-7/hour	3.8E-7/hour	8.8E-7/hour
BWR RI SYSTEMS			
RCIC	4.1E-8/hour	7.9E-7/hour	3.8E-6/hour
HPCI	3.6E-8/hour	7.0E-7/hour	3.3E-6/hour
LPCS	2.5E-7/hour	7.4E-7/hour	1.7E-6/hour

The AOV mean probabilities of failure on demand used in plant-specific IPE studies were compared with the results of this study. The PWR IPE mean values were generally consistent with the results of this study and the NUREG/CR-4550 generic values. Figures ES-1, ES-2, and ES-3 show RI systems for the PWR AFW, RHR, and CVCS systems, respectively. No comparison was made with BWR IPE mean values, since few BWR plant IPEs gave AOV failure probabilities on demand.

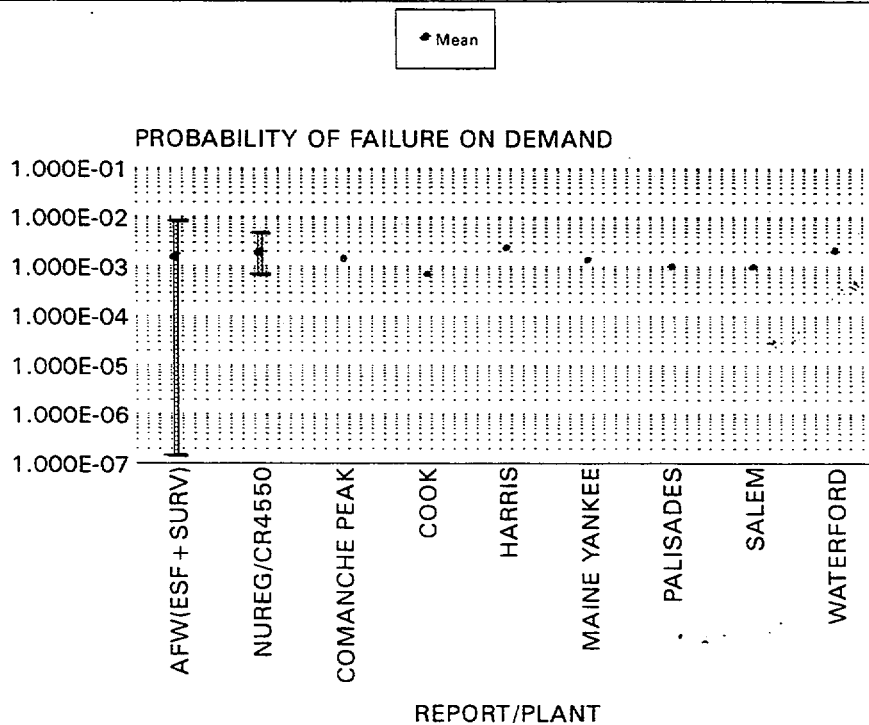


FIGURE ES-1
PWR AFW SYSTEM AOV PROBABILITY OF FAILURE ON DEMAND
COMPARISON WITH VALUES USED IN IPEs

FIGURE ES-3
PWR CVCS SYSTEM AOV PROBABILITY OF FAILURE ON DEMAND
COMPARISON WITH VALUES USED IN IPES

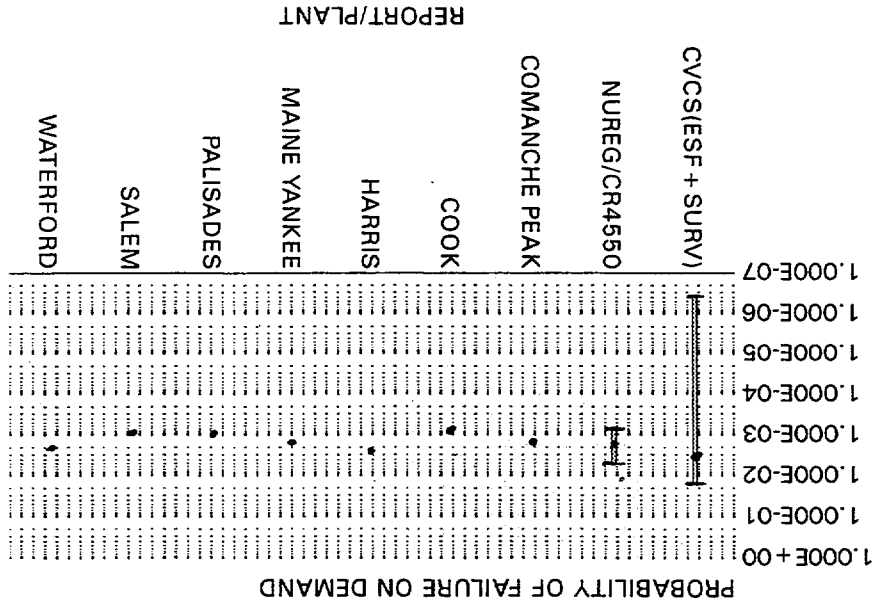
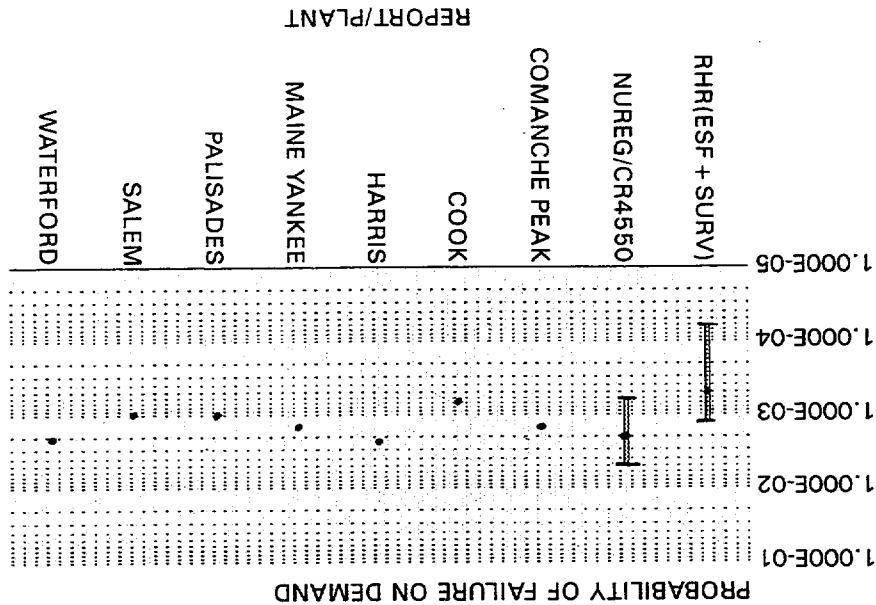


FIGURE ES-2
PWR RHR SYSTEM AOV PROBABILITY OF FAILURE ON DEMAND
COMPARISON WITH VALUES USED IN IPES



For the PWR RI systems during the 1987–1995 period, there was a statistically significant decreasing failure trend (see Figure ES-4, below). For BWR RI systems, no statistically significant trend was identified. Both the maintenance rule and voluntary industry joint owners group initiatives were begun during this period. While there was insufficient information available to conclude whether these initiatives caused the trend, an improvement in performance had occurred.

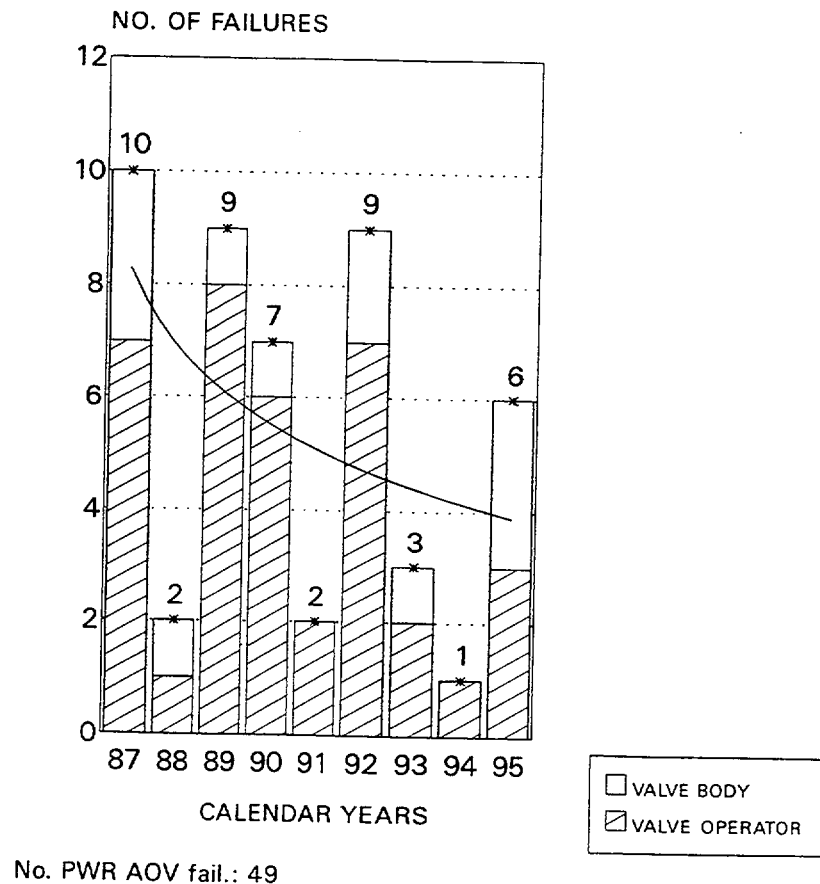


FIGURE ES-4
PWR AOV FAILURE TREND

Analysis of failure rates, as a function of component-years, showed no significant variance among the PWR plant age groups (three groups of approximately equal size, from older to newer plants by commercial operations date). The review of plant age groups did not show evidence of an increase in failure rates for any plant age groups due to aging mechanisms. For BWRs, failure data was too sparse for trending failure rates by plant age group.

The number of complete AOV common-cause failures (CCF) identified in this study was consistent with the expected number based on the CCF database parameters for the combined PWR and BWR complete failure population used in this study.

The AOVs have two subcomponents (valve body and valve operator). The valve operator was the biggest contributor to AOV failures (76%). Although valve operators were also the biggest contributors to BWR AOV failures, the number of failures (6) was too sparse to use. Figure ES-5 shows the PWR AOV failure apportionment.

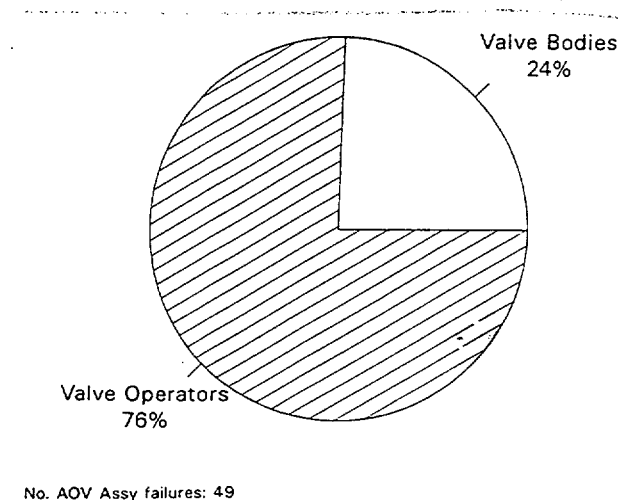


FIGURE ES-5
PWR AOV SUBCOMPONENT FAILURE APPORTIONMENT

Failures of AOV assemblies in PWR RI systems were mainly due to age/wear (47%). Figure ES-6 shows the PWR AOV assembly failure causes.

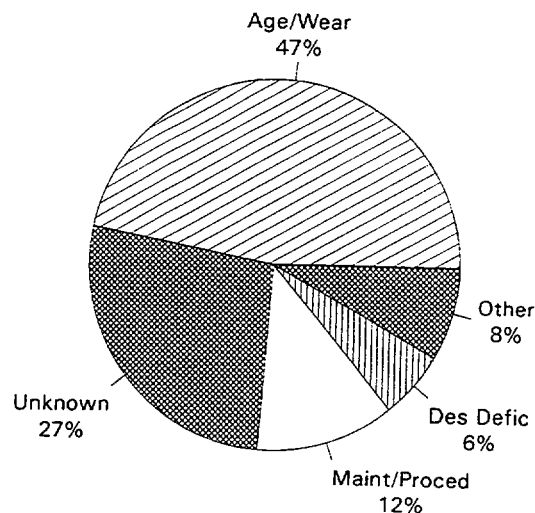


FIGURE ES-6
PWR AOV ASSEMBLY FAILURE CAUSES

FOREWORD

This report provides information relevant to the performance of air-operated valves (AOVs). It summarizes the failure and event data used in the analysis and evaluation. The results, including failure probabilities and engineering insights, are intended to support several risk-informed regulatory activities. This includes providing information to enhance plant inspections of risk-important systems and information used to support staff technical reviews.

Findings and conclusions from the analysis of AOVs, which are based on 1987–1998 operating experience, are presented in the Executive Summary and Section 5. The results of risk-based analysis and engineering analysis are presented in Sections 3 and 4, respectively. Information to support risk-informed regulatory activities and engineering analysis related to AOVs is summarized in Table F-1. This table provides a condensed index of risk-important data and data for engineering insights in the text discussions, tables, figures, and appendices.

The application of results is intended on an industry-wide basis for AOVs. Plant-specific application may require a more detailed review of the relevant Licensee Event Reports (LERs) and in-plant validation of plant-specific Nuclear Plant Reliability Data System (NPRDS) failure history data cited in this report. Factors such as design and application of specific AOVs, test and maintenance practices, availability, and response to regulatory initiatives would need to be considered in light of specific information provided in LER and NPRDS failure records. Other documents such as plant specifications, logs, reports, and inspection reports should be reviewed during plant inspections to supplement the information contained in this report.

In addition, a review of recent LERs and plant-specific information in NPRDS or the Equipment Information Exchange (EPIX) may yield indications of whether performance has undergone a significant change since the last year of this report. A search of the LER database can be conducted through the NRC's Sequence Coding and Search System (SCSS) to identify the AOV events that occurred after the period covered by this report. SCSS is accessible by NRC staff from the SCSS home page (<http://scss.ornl.gov/>) or in the Public Document Room (PDR). Nuclear industry organizations and the general public can obtain information from the SCSS on a cost recovery basis by contacting the Oak Ridge National Laboratory directly. NPRDS archival data (through 1996) and EPIX failure data is proprietary information that is maintained by the Institute of Nuclear Power Operations (INPO). NRC staff and contractors can access that information through the EPIX database.

Common-cause failures used in this study were obtained from the Common Cause Failure (CCF) Database. NRC staff and contractors can access the plant-specific CCF information through the CCF database which is available on CD-ROM and has been provided to the NRC Regions and NRC Office of Nuclear Reactor Regulation (NRR).

Table F-1
Summary of Risk-Important Information and Engineering Analysis For AOVs

1.	Risk-based analysis of operational data: calculation results	Section 3.1
2.	AOV probability of failure on demand	Table A, Appendix I
3.	AOV standby failure rate	Section 2.4, Table B
4.	Common-cause failure events	Section 3.2, Table C
5.	Comparison with IPEs	Section 3.3, Figures 3 - 5
6.	Failure trend analysis	Section 4.1, Figure 6, Appendix III
7.	Component trends in time	Section 4.2, Figure 7, Appendix II
8.	Failures of subcomponents and their causes	Section 4.3, Figures 8 & 9, Appendix III
9.	Related issues: Generic Letters, Generic Safety Issues, and Information Notices	Section 4.4, Table D
10.	Data source inputs for failures and demands	Appendix IV

ACKNOWLEDGMENTS

We thank our colleague Dr. Dale M. Rasmuson for his technical assistance in reviewing and presenting the statistical data. We also thank our colleague Erul Chelliah for his assistance in reviewing and verifying technical data and results.

ACRONYMS

AFW	auxiliary feedwater system
AOV	air-operated valve
ASME	American Society of Mechanical Engineers
BWR	boiling water reactor
CCF	common-cause failure
CCW	component cooling water system
CVCS	chemical and volume control system
EPIX	Equipment Performance and Information Exchange
ESF	engineered safety features
HPCI	high pressure coolant injection system
HPI	high pressure safety injection system
INEEL	Idaho National Engineering and Environmental Laboratory
INPO	The Institute of Nuclear Power Operations
IPE	individual plant examination
IST	inservice testing
JOG	joint owners group
LER	Licensee Event Report
LPCS	low pressure core spray system
MSIV	main steam isolation valve
NPRDS	Nuclear Plant Reliability Data System
NRC	U.S. Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation
ORNL	Oak Ridge National Laboratory
PORV	power-operated relief valve
PRA	probabilistic risk assessment
PWR	pressurized water reactor
RCIC	reactor core isolation cooling system
RHR	residual heat removal system
RI	risk-important
SCSS	Sequence Coding and Search System

COMPONENT PERFORMANCE STUDY AIR-OPERATED VALVES, 1987–1998

1. INTRODUCTION

1.1 Purpose

This report provides the performance evaluation of air-operated valve (AOV) assemblies in the pressurized water reactors (PWR) and in the boiling water reactors (BWR) risk-important (RI) systems during the period 1987 through 1998. The objectives of this study are: (1) to determine the reliability of AOV assemblies and compare the results with estimates in probabilistic risk assessments (PRAs) and individual plant examinations (IPEs) and (2) to review the operational data from an engineering perspective to determine trends and patterns and gain insights into component performance.

This study provides an engineering analysis of the factors affecting component reliability and determined whether trends and patterns were present in the AOV operating data for the 1987–1995 period. This study was based on the actual operating history of AOVs for these safety-related, RI systems. The reliability parameters calculated in this study are the probability of failure on demand and standby failure rate. Supplemental failure and demand data for 1996–1998 from operational events (Engineered Safety Features actuations reported in Licensee Event Reports) was added to the 1987–1995 data for estimating the AOV probabilities of failure on demand when the data populations were the same.

1.2 Background

The U.S. Nuclear Regulatory Commission (NRC) PRA Policy Statement directs the staff to increase the use of PRA technology in all regulatory matters. Accordingly, the Office of Nuclear Regulatory Research (RES) Division of Risk Analysis and Application (DRAA) monitors and reports on the functional reliability of risk-important systems in commercial nuclear power plants.

Over the past decade, the NRC has issued studies applicable to AOV risk-important systems, AOV components or their subcomponent failures, failure on demand probabilities, and trends and patterns. The following provides a listing of these studies:

1. AEOD/C701, "Air System Problems at U.S. Light Water Reactors," March 1987 (Ref. 1)

2. AEOD/E706, "Inadequate Mechanical Blocking of Valves," March 31, 1987 (Ref. 2)
3. NUREG-1275, Vol. 2, "Operating Experience Feedback Report — Air Systems Problems," December 1987 (Ref. 3)
4. NUREG-1275, Vol. 6, "Operating Experience Feedback Report — Solenoid Valve Problems," February 1991 (Ref. 4)
5. NUREG/CR-5497 (INEEL/EXT-97-01328), "Common Cause Failure Parameter Estimations," October 1998 (Ref. 5)
6. NUREG/CR-5500, Vol. 1, "Reliability Study: Auxiliary/Emergency Feedwater System, 1987-1995," August 1998 (Ref. 6)
7. NUREG/CR-5500, Vol. 9 (INEEL/EXT-99-00373), "High Pressure Safety Injection System Reliability, 1987–1997," October 2000 (Ref. 7)
8. NUREG-1275, Vol. 13, "Evaluation of Air-Operated Valves at U.S. Light Water Reactors," February 2000 (Ref. 8)
9. NUREG/CR-6644(INEEL-95/0550), "Generic Issue 158: Performance of Safety-Related Power Operated Valves Under Operating Conditions September 1999 (Ref. 9)

1.3 Overall Report Structure

This report is arranged in six sections. Section 1 provides the introduction. Section 2 describes the scope of the study, risk-important systems, the AOV assembly and its subcomponent boundaries, and the methodology used for operational data collection and analysis. Section 3 provides the risk-based analysis of operational data, the calculation results for estimating AOV probabilities of failure on demand and standby failure rate, the contingency test for the data population, the comparison of AOV probability values with those in IPEs and other sources, and the regulatory implications of this component performance study. Section 4 provides the engineering analyses including failure trend analysis, component trends in time, the failure characteristics and their causes, a brief discussion and listing of NRC regulatory initiatives related to AOVs, and engineering insights resulting from the various analyses. Section 5 provides a summary of results, including AOV failure probabilities and engineering insights. Section 6 lists references used in the report.

The appendices provide related data used in this report and evaluation results. Appendix I provides the estimated probabilities of failure on demand

and calculated standby failure rates. Appendix II provides tables of data for each plant age group used to plot the component trends in time and evaluation of aging effects on AOVs. Appendix III provides data used for engineering analysis and insights for failure trends and patterns. Appendix IV provides operational data inputs for reported failures and estimated demands from the NPRDS database and LERs (SCSS database).

2. SCOPE OF STUDY

2.1 Risk-Important Systems and Components

The term "Application Coded" used in this study refers to risk-important components or subcomponents that are functionally designated within a specific system by the NPRDS. An example of PWR AFW system and BWR HPCI system AOV subcomponents that were separately Application Coded in NPRDS are as follows:

COMP. ASSY	SUBCOMP.	REACTOR TYPE	RI SYSTEM	APPLICATION CODE DESCR.
AOV	Valve, damper	PWR	AFW	Aux/Emerg Fdwtr to S/G Isol Valve
AOV	Valve operator	PWR	AFW	Aux/Emerg Fdwtr to S/G Isol Valve Operator
AOV	Valve, damper	BWR	HPCI	HPCI Disch to Fdwtr Check Valve
AOV	Valve operator	BWR	HPCI	HPCI Disch to Fdwtr Check Valve Operator

The following PWR risk-important (RI) systems use Application Coded AOVs:

- auxiliary/emergency feedwater (AFW) system
- high pressure safety injection/SI (HPI) system
- chemical and volume control system (CVCS)
- residual heat removal/low pressure injection (RHR) system
- component cooling water system (CCW)

For this study, the HPI system includes AOVs associated with high head safety injection flow paths.

The following BWR risk-important systems use Application Coded AOVs:

- reactor core isolation cooling (RCIC) system
- high pressure coolant injection (HPCI) system
- low pressure core spray (LPCS) system

2.2 AOV Assembly Description and Boundaries

For this study, an AOV assembly consists of valve body and pneumatic operator subcomponents. The valve body is generally a globe or butterfly type. The pneumatic operator is generally a piston or diaphragm type actuator, designed to accommodate the system pressure/temperature requirements and the thrust requirements necessary for the valve's functional operation. Main steam isolation valves (MSIVs) and power-operated relief valves (PORVs) are excluded from this study as these are valves with different design and operating features.

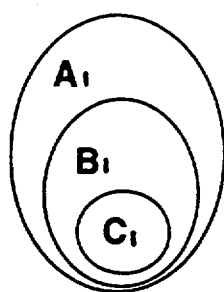
The component boundaries are the AOV assembly, its subcomponents described above, and the piece parts of the subcomponents. The piece parts of the valve body are the stem, packing, and internals. The pneumatic operator piece parts may include piston internals/seals or diaphragm, positioner, mechanical linkage, volume booster, pilot valve, bolting, air regulator, air line, and wiring/contacts. Failures associated with instrument air systems (e.g., valves, regulators, backup accumulators, etc.) that are not integral to the AOV assembly are excluded in this analysis.

2.3 DATA COLLECTION

Data collection and reporting for the Nuclear Plant Reliability Data System (NPRDS) were terminated at the end of 1996. Therefore, the NPRDS does not have any failure information for the period 1997 and later. Furthermore, the 1996 failure data reported in NPRDS was not as consistent as for the 1987–1995 period (the industry was transitioning for the termination of NPRDS). The Institute for Nuclear Power Operations (INPO) has recently implemented a new component database called the Equipment Performance and Information Exchange (EPIX) system. This system is intended to replace the NPRDS system and yields additional information, such as demands and unavailability. At the time of this analysis, the EPIX system was not considered to be sufficiently mature to provide a complete data source for the 1996–1998 period for this study. Where applicable in the development of probability of failure on demand estimates for this study, the SCSS database of ESF failure and demand data (reported in LERs) were used for the 1996–1998 period.

The NPRDS database was used to obtain the number of Application Coded AOV assembly subcomponents. This was done for each selected RI system in PWRs and BWRs for each plant. The values developed in Appendix IV were also used in the development of all other appendices.

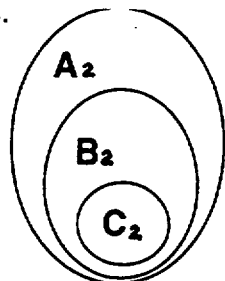
A detailed review and evaluation was performed of the licensee event reports (LERs) and the NPRDS failure histories to determine the total number of AOV failures used in this study. Only "complete" (i.e., catastrophic) failures were included in the failure count. For AOV valve body and valve operator subcomponents, the NPRDS "failure to close" (FC), "failure to open" (FO), and "failure to operate as required" (OR) failure modes were used for estimating probability of failure on demand. The OR failure mode included both failure to open and failure to close failure modes. Figure 1 illustrates the relationship between various NPRDS database failure data subsets.



- A1** All AOV assembly subcomponent failures as "complete"/catastrophic failure category (1987–1995).
- B1** Subset — AOV Application Coded subcomponent failures for risk-important systems.
- C1** Subset — AOV Application Coded subcomponent failures occurring during surveillance tests.

FIGURE 1
NPRDS DATABASE AOV FAILURES

The SCSS database was used to determine the number of AOV failures, reported in LERs, that occurred during surveillance tests or that were associated with an Engineered Safety Features (ESF) actuation. The NPRDS database was used to obtain the number of surveillance test failures for each AOV subcomponent. Surveillance test failures that were reported in LERs were excluded from the NPRDS failure counts, but included in the LER failure counts. This was done to prevent "double count" of failures. Figure 2 illustrates the relationship between various SCSS database (LERs) failure data subsets.



- A2** All AOV assembly failures (1987–1998).
- B2** Subset — AOV failures for risk-important systems.
- C2** Subset — AOV failures associated with ESFs or occurring during surveillance tests.

FIGURE 2
SCSS DATABASE AOV FAILURES

AOV failures that occurred during surveillance testing were directly linked with surveillance test demands to assure that surveillance test probability of failure on demand estimates were valid. Similarly, ESF failures were linked with ESF demands to estimate ESF probability of failure on demand. For most plant RI systems there are multiple trains, each train with several AOVs. Those other train AOVs that might have been actuated during pre-test or post-test system train alignment were not included in the surveillance test failure counts used in this study.

When it was determined by statistical means that the ESF failures and demands were in the same population as the surveillance test failures and demands, the total number of demands was the sum of the ESF demands and the surveillance test demands. Otherwise, the larger population surveillance test demands (and associated failures) were used to calculate the AOV unreliability.

The first step for estimating ESF demands was to determine ESF actuations, and then to determine which component type and how many components of each type were actuated by this type of demand. Other demands that may have occurred during plant operation, startup or shutdown that did not result in ESF actuations were not included in the ESF demand determination, nor were any associated failures included. However, inadvertent and spurious demands and manual actuations associated with an ESF (e.g., a reactor trip) were considered ESF demands. The SCSS LER database was used for the PWR and BWR RI systems LERs that were coded with "ESF Actuations" and those coded as "SCRAMS and Shutdowns." Each LER full text was reviewed to determine whether the selected systems were actuated, the number of trains actuated by the ESF; and the best estimate of the number of each Application Coded AOV actuated based on the plant-specific train configuration.

The second step in estimating the total number of demands was the use of NPRDS testing frequencies as the basis for surveillance test demands. This was done for the NPRDS Application Coded, functionally designated AOV assembly subcomponents in the RI systems (see Section 2.1 for the description of the AOV assembly). An estimate was made for the AOV assembly testing frequency that used the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI Inservice Testing (IST) interval requirements (as required by the Technical Specifications), the system, and the subcomponent function in the AOV assembly. Demands associated with a surveillance test that occurred during train alignment and return to the "as found" condition of a system/train were not included in the total number of demands, nor were corollary failures included in the failure count. Although the Technical Specifications generally require a system test once per refueling cycle, no additional demands were

included because the surveillance test frequencies used in this study (e.g., monthly, quarterly, and once per refueling outage) were assumed to envelope these refueling cycle demands.

The total number of demands for the AOVs in a specific system was the sum of AOV ESF demands and surveillance test demands, where the latter is the sum of the products of the AOVs and their estimated testing frequencies over the 9-year period (1987–1995) and the former (ESFs) is extended to the 12-year period (1987–1998). However, this method is applicable when the ESF data and surveillance test data determined by statistical methods to be in the same population (see Section 3.1 for contingency tests). Otherwise, the surveillance test demands (and associated failures) were used to calculate the AOVs unreliability.

The probability of failure on demand for AOVs was estimated by dividing total AOV failures by total AOV demands (i.e, ESF failures + surveillance test failures divided by ESF demands + surveillance test demands) when the ESF data and surveillance test data were statistically shown to be in the same population. This represents an unbiased sample of the AOV performance data for calculating the reliability of AOVs because:

- The ESF demands and surveillance tests reasonably reflect the ability of the AOVs to perform their risk-significant function.
- It is possible to count both the demands and the failures for these groups.
- It is possible to determine statistically if data from ESF demands and surveillance tests can be pooled.

AOV surveillance tests and ESF actuations do not typically reflect design-basis conditions. Therefore, they do not characterize the ability of the AOVs to perform under design-basis conditions which are generally more severe and occur less frequently than the risk-significant safety function conditions.

2.4 Operational Data Analysis

A contingency test was performed to **not reject** or to **reject** the hypothesis that failure and demand data from surveillance testing of Application Coded AOVs were in the same population as ESF failure and demand data. The analysis was performed using data for the AOVs in the PWR and BWR RI systems during the 1987–1995 period. A subsequent contingency test is performed to determine whether ESF data from the 1996–1998 period is in the same population as the combined ESF + surveillance test data from the 1987–1995 period.

The approximate method for contingency tables (chi-square, one degree of freedom, 0.95 quantile), was used for the **not reject** hypothesis that the ESF and surveillance test data are from the same population ($\chi^2 < 3.84$). The contingency table provides a short-cut method of computing chi-square using the following 2X2 table and formula:

$$\chi^2 = \frac{n(ad - bc)^2}{k} ; \text{ where: } n = a + b + c + d \text{ and } k = (a+b)(c+d)(a+c)(b+d)$$

	ESFs	SURVEILLANCE TEST	TOTAL
NO. of FAILURES	<i>a</i>	<i>b</i>	<i>(a + b)</i>
NO. of SUCCESSES	<i>c</i>	<i>d</i>	<i>(c + d)</i>
TOTAL (DEMANDS)	<i>(a + c)</i>	<i>(b + d)</i>	<i>n</i>

Alternate Method (to correct for continuity), formula:

$$\chi^2 = \frac{n(|ad-bc| - n/2)^2}{k}$$

Bayes Method

The Bayes method (Ref. 11), as applied to this study for AOVs by plant system, assumes that the probability of failure on demand varies from plant to plant according to a beta distribution. The parameters for this distribution were estimated from the pooled data by maximum likelihood. For each plant, this distribution was used as a Bayes prior distribution, and updated with the plant-specific failure data. This method was used in this study for the PWR and BWR RI systems.

Standby Failure Rate

The average standby failure rate (λ) for AOVs in each system is based on the data for the 9-year period (1987–1995), using the following equation:

$$\lambda = \frac{f}{(nc)(coy)(8760)}, \text{ failures per component-hour}$$

where: *f* = the number of failures during the period

nc = the number of AOVs in each plant for the system

coy = the actual number of calendar operating years during the 9-year period

8760 = the number of hours in a calendar year

The 90% confidence interval was also calculated for λ in each system.

3. RISK-BASED ANALYSIS

This section provides the risk-based analysis of operational data, the calculation results for estimating AOV probabilities of failure on demand and standby failure rate, the contingency test for the data population, the comparison of AOV probability values with those in IPEs and other sources, and the regulatory implications of this component performance study.

3.1 Calculation Results

Appendix I provides tables applicable to the AOV probability of failure on demand by the selected systems in the PWR and BWR plants. The summary of results of the contingency tests for the hypothesis that ESFs and surveillance test data are in the same population is as follows:

<u>PWR RI SYSTEM</u>	<u>HYPOTHESIS</u>	<u>BWR RI SYSTEM</u>	<u>HYPOTHESIS</u>
HPI	Not Determinable	RCIC	Not Rejected
AFW	Not Rejected	HPCI	Not Rejected
RHR	Not Rejected	LPCS	Not Rejected
CVCS	Not Rejected		
CCW	No ESF Data		

For PWR HPI system AOVs, during the 1987–1995 period, the contingency test rejected the hypothesis that the ESF failures and demands were in the same population as the surveillance test failures and demands. For the PWR HPI system AOVs (1987–1995 data), there were no surveillance test or ESF failures. With no failures, the contingency test could not be performed. In addition, the HPI system has few plants (3) with one Application Coded AOV in each plant that are subject to an ESF actuation, resulting in sparse ESF demand data. For the PWR CCW system, there were no ESF failures or ESF demands. Therefore, the more extensive surveillance test data (1987–1995) was used for probability of failure on demand estimates for the PWR HPI and CCW systems.

For the balance of PWR and BWR RI systems, the contingency tests did not reject the hypothesis that the ESF failures and demands were in the same population as the surveillance test failures and demands. Therefore, the Bayes 90% intervals for ESF + Surveillance Test (1987–1995) + ESF (1996–1998) probability of failure on demand was used for these systems.

The generic failure probabilities used in PRAs are presently provided in terms of probability of failure on demand and probability of failure per operating hour. In this study, probability of failure on demand was used because data was available

to allow matching failures to demands. Sufficient data on hours of operation from LERs and NPRDS was not adequate to compare with generic failure rates. The generic failure probability on demand values used in this study are from NUREG/CR-4550 "failure to operate" values for air-operated valves (Ref. 12).

Table A shows the AOV probability of failure on demand values for the 1987–1998 period.

TABLE A AOV PROBABILITY OF FAILURE ON DEMAND (1987–1998)			
	LOWER BOUND	MEAN	UPPER BOUND
NUREG/CR-4550	5.4E-4	2E-3	4.8E-3
PWR RI SYSTEMS			
ESF + SURV. TEST (1987–1998 Period):			
auxiliary feedwater (AFW)	4.6E-6	1.8E-3	6.9E-3
residual heat removal (RHR)	6.1E-5	5.2E-4	1.3E-3
chemical and volume control system(CVCS)	3.5E-7	3.4E-3	1.5E-2
SURV. TEST (1987–1995 Period):			
high pressure injection (HPI)	4.8E-6	3.6E-3	9.5E-3
component cooling water (CCW)	6.7E-5	5.8E-3	2.1E-2
BWR RI SYSTEMS			
ESF + SURV. TEST (1987–1998 Period):			
reactor core isolation cooling (RCIC)	3.5E-4	3.9E-3	7.7E-3
high pressure coolant injection (HPCI)	4.3E-4	3.6E-3	9.5E-3
low pressure core spray (LPCS)	2.9E-15	2.1E-3	1.2E-2

The results shown in Table A indicated that the Bayes 90% interval AOV estimated probabilities of failure on demand distributions for PWR and BWR RI systems were consistent with the generic value range for AOVs from NUREG/CR-4550 (Ref.12), although the mean value for the PWR RHR system (5.2E-4) is about a factor of 4 lower than the generic mean value (2E-3).

The PWR and BWR probability of failure on demand yearly trend analyses did not show statistically significant trends for the risk important systems in this study.

Table B shows the average standby failure rates based on 1987–1998 failure data for the combined ESF and surveillance tests where the hypothesis was not rejected.

TABLE B
AOV STANDBY FAILURE RATE (1987–1998)

	<u>LOWER BOUND(λ_l)</u>	<u>MEAN(λ)</u>	<u>UPPER BOUND(λ_u)</u>
PWR RI SYSTEMS			
auxiliary feedwater (AFW)	4.8E-7/hour	8.2E-7/hour	1.3E-6/hour
high pressure injection (HPI)	4.4E-10/hour	1.1E-7/hour	4.3E-7/hour
residual heat removal (RHR)	6.9E-9/hour	1.3E-7/hour	6.4E-7/hour
chemical and volume control sys(CVCS)	4.0E-7/hour	6.0E-7/hour	8.5E-7/hour
component cooling water (CCW)	1.3E-7/hour	3.8E-7/hour	8.8E-7/hour
BWR RI SYSTEMS			
reactor core isolation cooling (RCIC)	4.1E-8/hour	7.9E-7/hour	3.8E-6/hour
high pressure coolant injection (HPCI)	3.6E-8/hour	7.0E-7/hour	3.3E-6/hour
low pressure core spray (LPCS)	2.5E-7/hour	7.4E-7/hour	1.7E-6/hour

Note: There were no HPI failures during the 1987–1998 period. A Jeffreys non-informative prior was used to determine the standby failure rate.

3.2 Common-Cause Failure Events

A review of the common-cause failure (CCF) database for the 1987–1995 period found one AOV complete failure (listed in bold in table below) in the selected risk-important systems with the scope of this study's criteria [e.g., complete failures and Application Coded AOVs and ESF or surveillance testing and with fail-to-open (FO), fail-to-close (FC) or fail-to-operate as required (OR) failure modes]. This is consistent with the expected number of failures, based on the CCF database parameters, for the combined PWR and BWR complete failure population (55) used in this study. Table C lists all AOV failures in the CCF database for 1987–1995. CCF numbers that include **XXX** denote proprietary NPRDS source failures. For these CCFs, the plant Identification (PLT ID) column gives the coded identifier for the plant whose docket number is listed in the CCF database for the **XXX**. The detailed CCF failure descriptions are available to NRC staff and inspectors in the CCF database (See Foreword).

TABLE C
AOV FAILURES IN THE CCF DATABASE (1987-1995)

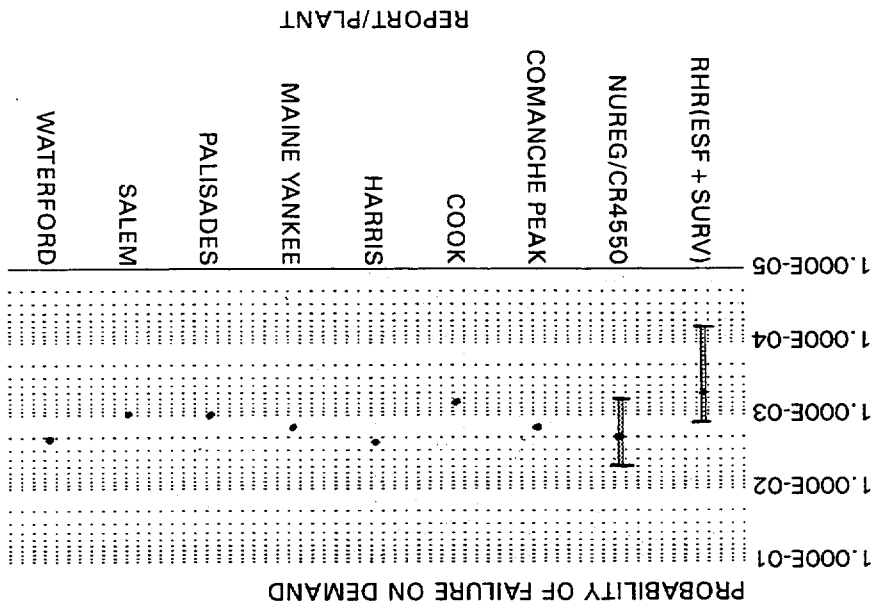
<u>SYS</u>	<u>COMPLETE/ DEGRADED</u>	<u>APPLIC. CODED</u>	<u>ESF/ SURV.</u>	<u>FAIL. MODE</u>	<u>CCF NUMBER</u>	<u>PLT ID/ DKT</u>
AFW	Degraded	NO	NO	FC	L-528-87-2682-CC	528
AFW	Degraded	YES	SURV	OR	N-XXX-88-0849-VR	55
AFW	Degraded	YES	NO	OR	N-XXX-88-0850-00	55
AFW	Degraded	YES	NO	OR	N-XXX-88-0851-00	55
AFW	Complete	YES	NO	OR	N-XXX-88-0852-CC	55
AFW	Complete	YES	SURV	FC	N-XXX-90-0844-CC	55
HPCI	Degraded	YES	NO	FO	N-XXX-91-0875-CC	37
AFW	Degraded	YES	NO	OR	N-XXX-91-0855-00	58
AFW	Degraded	YES	NO	OR	N-XXX-92-0839-00	30
AFW	Degraded	YES	ESF	OR	L-316-93-0763-CC	316
AFW	Degraded	NO	NO	OR	L-286-93-0864-SA	286
AFW	Degraded	NO	NO	OR	N-XXX-94-2442-CC	31
AFW	Degraded	YES	SURV	FC	L-309-95-2441-LI	309
AFW	Degraded	YES	SURV	OR	N-XXX-95-2443-CC	99

3.3 Comparison With IPEs and Other Sources

The AOV failure probabilities on demand developed for the PWR RI systems were compared with a selected group of plant-specific Individual Plant Examinations (IPEs) as shown in Figures 3 through 5. The PWR plants IPE mean values were generally consistent with the results of this study and the NUREG/CR-4550 generic values. No comparison was made with BWR IPE values, as few BWR plants IPEs provided AOV failure probabilities on demand.

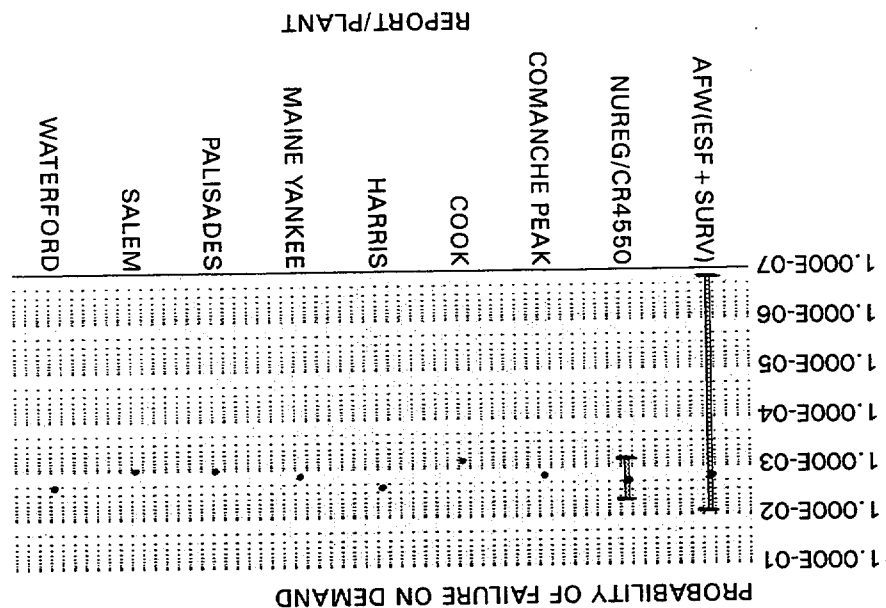
This comparison reflects readily available (docketed) IPE/PRA information. Licensees which have updated their IPE/PRA without providing docketed information relating to AOVs are not reflected in this comparison.

PWR RHR SYSTEM AOV PROBABILITY OF FAILURE ON DEMAND -
COMPARISON WITH VALUES USED IN IPES



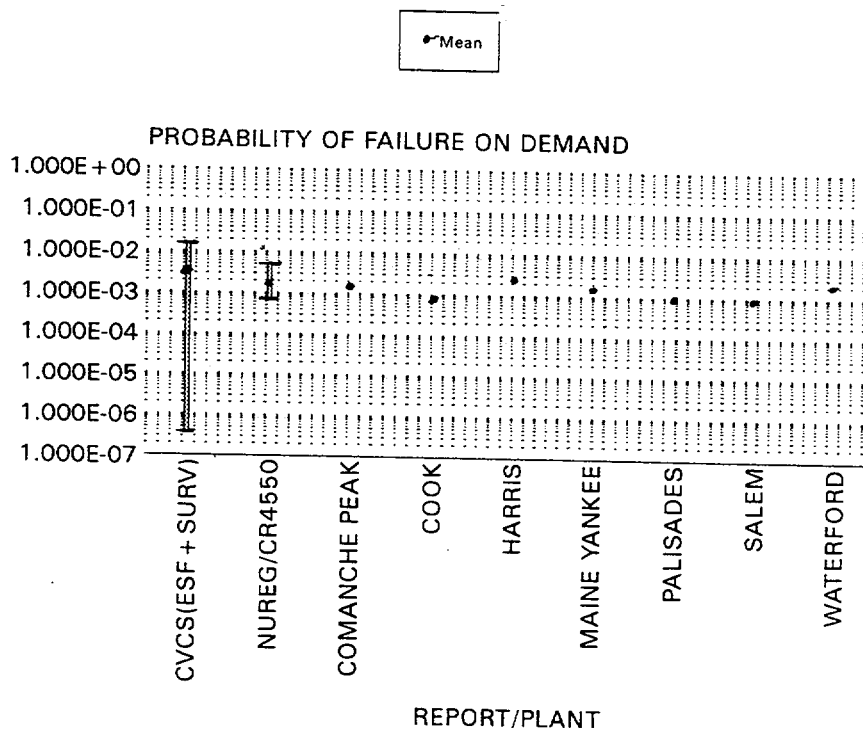
• Mean

PWR AFW SYSTEM AOV PROBABILITY OF FAILURE ON DEMAND -
COMPARISON WITH VALUES USED IN IPES



• Mean

FIGURE 4



**PWR CVCS AOV PROBABILITY OF FAILURE ON DEMAND -
COMPARISON WITH VALUES USED IN IPEs
FIGURE 5**

4. ENGINEERING ANALYSIS

This section provides the engineering analyses including failure trend analysis, component trends in time, the failure characteristics and their causes, a brief discussion and listing of NRC regulatory initiatives related to AOVs, and engineering insights resulting from the various analyses.

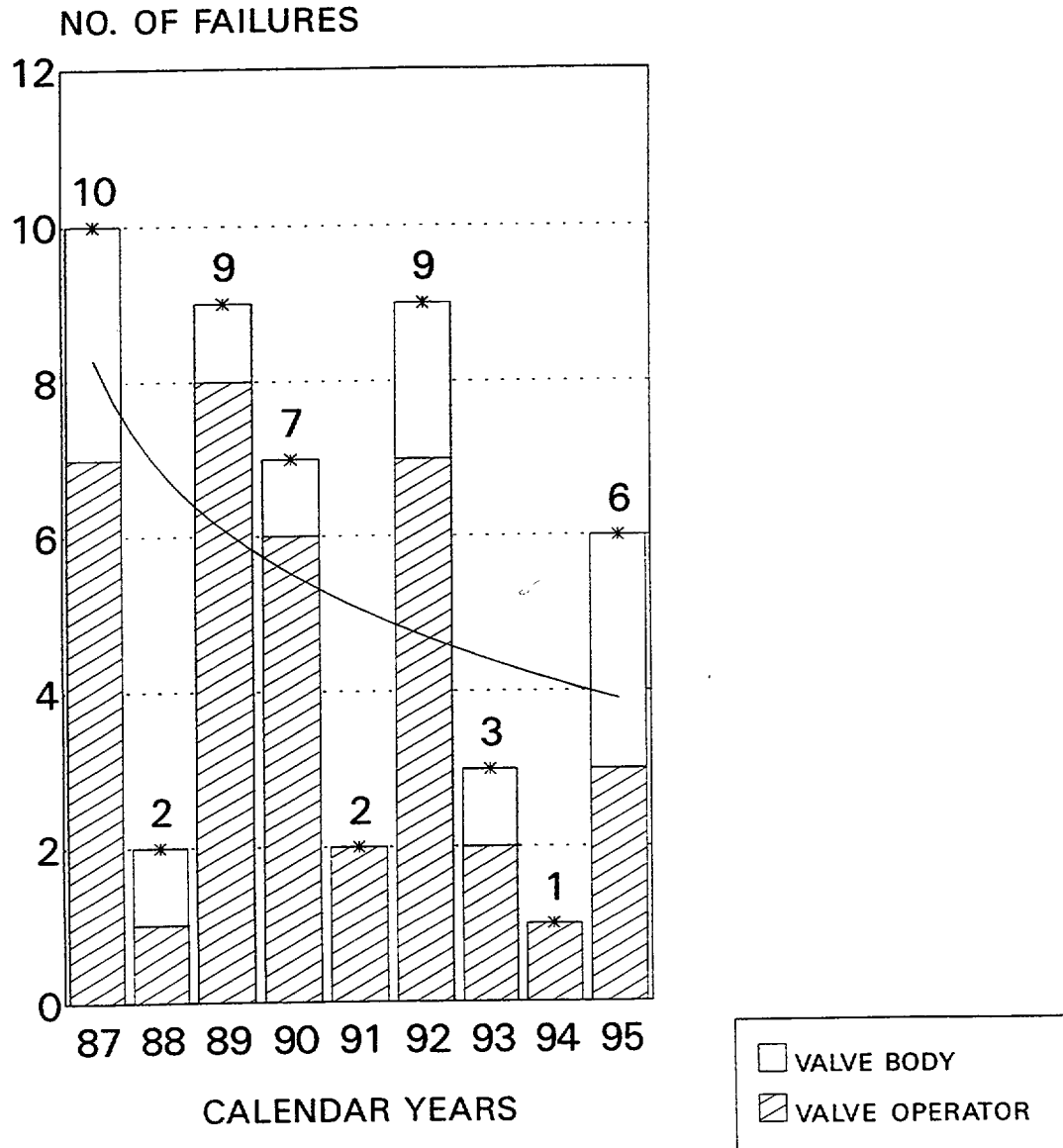
4.1 Failure Trend Analysis

Appendix III provides applicable data for trending of AOV failures. Failure trends of AOVs, shown for failures and failure fractions during the 1987–1995 period.

As indicated in Section 2.3, NPRDS failure data for 1996 was reported inconsistently by licensees and, therefore, was determined to be insufficient for trending purposes. Without NPRDS data, LER data from 1996 through 1998 was insufficient for trending purposes. Therefore, failure data for trending in this study used NPRDS and LER failure data for the 1987–1995 period.

For the PWR RI systems during the 1987–1995 period there was a statistically significant decreasing trend in the number of failures. Both the maintenance rule and voluntary industry joint owners group (JOG) initiatives were begun during this period. While there was not sufficient information to conclude whether these

initiatives caused the trend, it is noted that an improvement in performance has occurred. For BWR RI systems no statistically significant trend was identified. Figure 6 shows the PWR AOV failure trends for the 1987–1995.



No. PWR AOV fail.: 49

PWR AOV FAILURE TREND
FIGURE 6

4.2 Component Trends in Time

Methodology

The initial assumption made in this study, relative to aging effects on component assemblies, is that the rate of failure events over time (λ) is constant. Several evaluation methods were used to check this assumption. The reason for checking was to determine if any significant age-related increase in λ occurred among older plants. In order to conclude that an increase due to "aging" occurred, it would be necessary for all three of the following conditions to be present:

1. There was an increase in λ over time (a nonconstant failure rate that was increasing).
2. λ was higher for older plants.
3. The dominant contributor to failure was due to age/wear mechanisms.

When individual failure events are arranged in chronological order, a cumulative plot helps to show whether λ is constant throughout the period.

This study used an average failure rate, λ_{AVE} , equal to the total number of AOV failures for the 1987-1995 period, divided by the cumulative number of AOV component- years of standby operation during the period. Failure data from the 1996-1998 period was not included as it was for ESF failure and limited surveillance test failure data only.

The cumulative number of failures was plotted against the number of AOV component- years since the beginning of the study period (1987) for comparison with λ_{AVE} . This was done for plant age groups A, B, and C. The following table gives the definition of each plant age group and its apportionment, with the 109-plant total used for this study:

PLT AGE GROUP	COMMERCIAL OPERATION DATE	TOTAL NUMBER OF PLANTS	NUMBER OF PWR PLANTS	NUMBER OF BWR PLANTS
A	12/31/74 and Earlier	36	24	12
B	01/01/75 through 03/31/84	37	25	12
C	04/01/84 and later	36	24	12

The assumption (i.e., null hypothesis) that λ_{AVE} is constant during the study period for each plant age group and for the combined plant age groups was evaluated. The failure rates (λ_{AVE}) are the slope of the plots for each plant age group. Comparison between plant age groups were made to determine whether there was any indication of plant aging (e.g., higher slope for the older plant age groups than for the newer plant age groups). Another test for the null hypothesis that the failure rate is constant is the Laplace test. For this test, $L/2$ is defined as the midpoint of the cumulative number of component-years during the 1987-1995 period. If λ is constant, about half of the events should occur before $L/2$ and half afterwards. The criteria for not rejecting the null hypothesis is that the statistic U is approximately normal for a number of failures ≥ 3 (U is within ± 1.645 for the 0.95th and 0.05th quantiles, respectively, of the standard distribution). For a nonconstant failure rate (rejected null hypothesis) that is increasing ($U > +1.645$), possible aging exists. The formula for the U statistic is :

$$U = \frac{T - L/2}{L \sqrt{1/12n}} \quad \text{where: } n = \text{no. of failures, } T_i = \text{interval between failures in component-years, } T = \sum T_i / n$$

The mean time between failures was provided for information, using the reciprocal of the λ_{AVE} applicable to each PWR and BWR plant age group and the combined plant age groups.

Results

Appendix II provides tables applicable to component trends in time evaluations for AOVs. These analyses were performed to determine whether the failure rates were constant over time and whether the failure rates between older and newer plant age groups increased as an indication of possible aging. A comparison of plots of cumulative AOV failures over time to the applicable average failure rate (λ_{AVE}) plots and analyses indicated the following:

PWRs (see Figure 7) - For the PWR RI systems, an analysis of plant age groups did not show evidence of an increase in failure rates for any of the plant age groups due to aging mechanisms. Therefore, either aging impacts are not affecting reliability or replacement/repair restored equipment to normal performance regardless of plant age.

- For plant age group A, the assumed hypothesis that the failure rate was constant was not rejected. The value of U at the 10-percent significance level was -0.616 (> -1.645) and did not show any evidence of a nonconstant failure rate.
- For plant age group B, the hypothesis of a constant failure rate was rejected (decreasing). The value of U at the 10-percent significance level

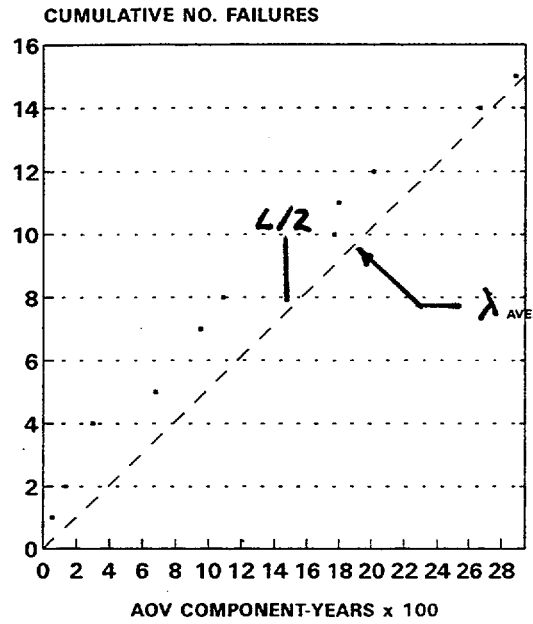
was -1.999 (<-1.645). Since the nonconstant failure rate is decreasing, there is no evidence to support component aging.

- For plant age group C, the hypothesis of a constant failure rate was not rejected. The value of U at the 10-percent significance level was -0.308 (>-1.645) and did not show any evidence of a nonconstant failure rate.
- When the average failure rates were compared among the plant age groups, plant age effects were assumed to be reflected by highest average failure rates for the older plant age group A, ranging to the lowest average failure rate for plant age group C. This assumption did not occur, where λ_{AVE} for A (0.005), B (0.004) and C (0.006) were very close together and did not provide evidence of plant age effects among the plant age groups.
- When the failure causes for PWR AOV assemblies were reviewed, age/wear causes (47%), and unknown causes (27%) were the more significant causes (see Figure 15). Therefore, age/wear mechanisms were the predominant cause of failure.

BWRs - For the BWR RI systems AOVs, the data was determined to be too sparse (6 failures during the 1987-1995 period) for trending analysis by plant age groups.

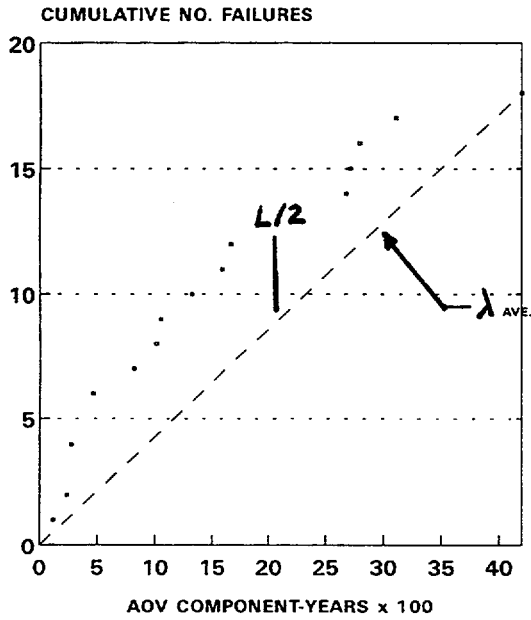
The analysis indicates no evidence to conclude that “aging” is adversely affecting the failure rate of the AOVs in this report because failure rates were not increasing over time and older plants did not exhibit a higher failure rate compared to newer plants. As noted in Section 4.3, age/wear is the dominant contributor to PWR AOV failures (BWR data is too sparse for analysis). However, the evidence does not indicate that failure rates are increasing or that older plants’ AOVs fail more often. It is not clear whether this is due to a lack of “aging” impacts or whether replacement/refurbishment of AOVs is responsible for the lack of an “aging” trend. Since specific component age information is not available, no additional assessments of causes for the lack of trends was possible.

AOVs - PLANT AGE GRP A
PWR RI SYSTEMS



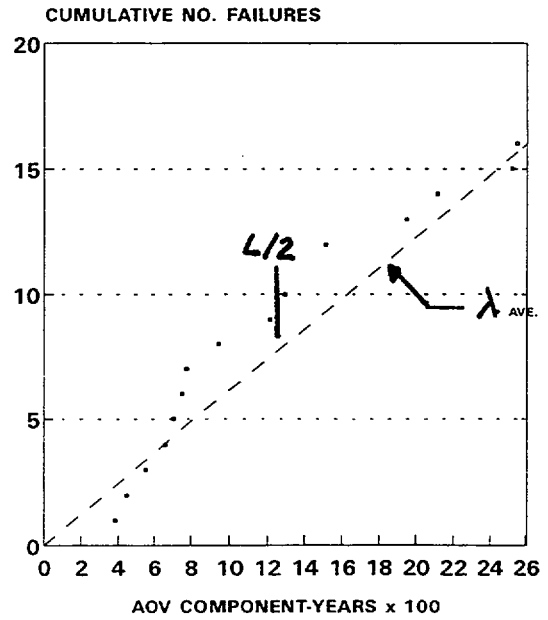
PERIOD: 1987-1995
No. fail.: 15

AOVs - PLANT AGE GRP B
PWR RI SYSTEMS



PERIOD: 1987-1995
No. fail.: 18

AOVs - PLANT AGE GRP C
PWR RI SYSTEMS



PERIOD: 1987-1995
No. fail.: 16

PWR AOV COMPONENT TRENDS IN TIME
FIGURE 7

FIGURE 7

4.3 Failure Characteristics and Their Causes

Methodology

The AOV assembly failures and causes were identified on a subcomponent level in the NPRDS database. For LER reported failures (SCSS database), sufficient information was provided to identify failed subcomponents and causes within the LER narrative and group these failures using the NPRDS categories. The apportionments were determined to provide insights into the predominant subcomponent failures and their causes by reactor type (i.e., PWR and BWR). For BWRs, however, the number of failures (6) was too sparse to provide insights.

The failure cause categories used in this study were as follows:

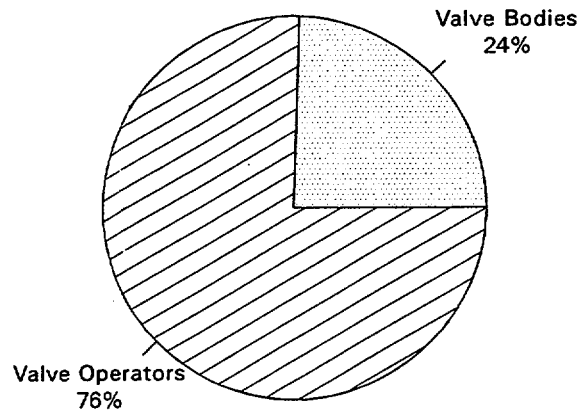
Age/Wear (AW)	Dirt/Contamination/Corrosion (DC)
Design Deficiency (DD)	Manufacturing Defect (MF)
Unknown (UK)	Debris/Foreign Material (DF)
Other Devices (OD)	Maintenance/Procedural Deficiencies (MP)

Results

Figure 8 shows the PWR AOV subcomponent and subcomponent parts failure apportionment. For PWRs, the evaluation of AOV subcomponent failure patterns determined that pneumatic operator failures accounted for greater than three-fourths of all AOV subcomponent failures.

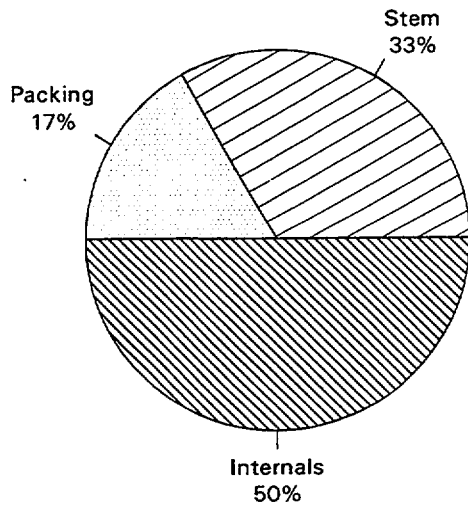
Failure causes for PWR AOV assemblies are illustrated in Figure 9. For the PWR RI systems, the causes were mainly due to age/wear (47%) and unknown (27%).

PWR RI SYSTEM AOVs



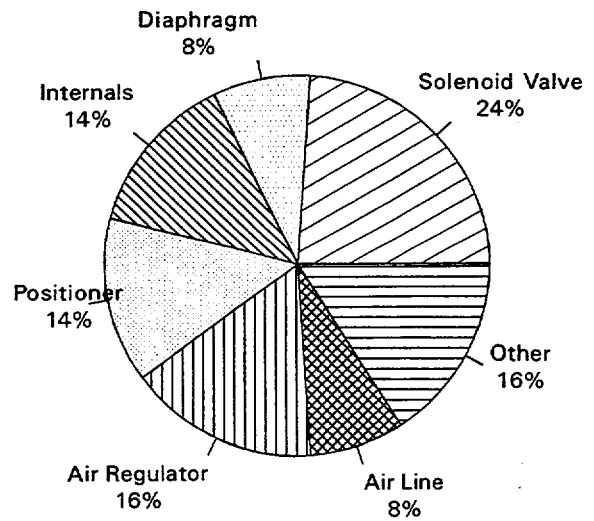
No. AOV Assy failures: 49

PWR RI SYSTEM AOVs
VALVE BODY SUBCOMPONENT PARTS FAILURES



No. AOV Valve Body failures: 12

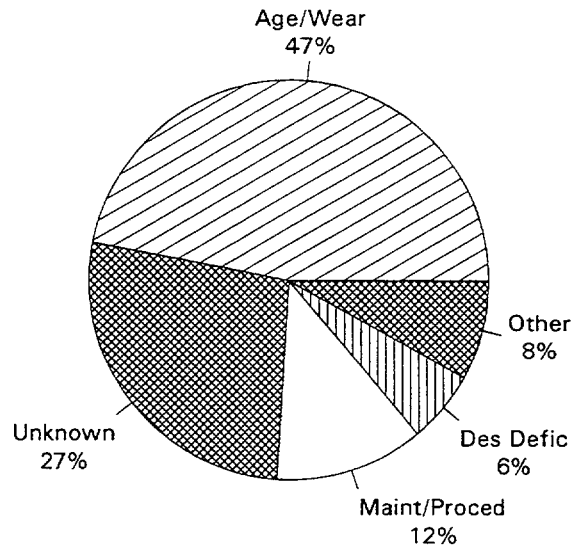
PWR RI SYSTEM AOVs
VALVE OPER. SUBCOMPONENT PARTS FAILURES



No. AOV Valve Oper. failures: 37

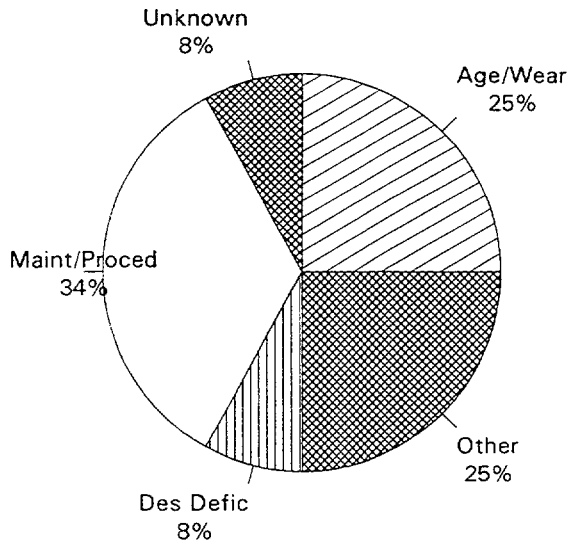
PWR AOV SUBCOMPONENT AND SUBCOMPONENT PARTS FAILURE APPORTIONMENT
FIGURE 8

**PWR RI SYSTEMS AOV ASSEMBLIES
ALL SUBCOMPONENTS**



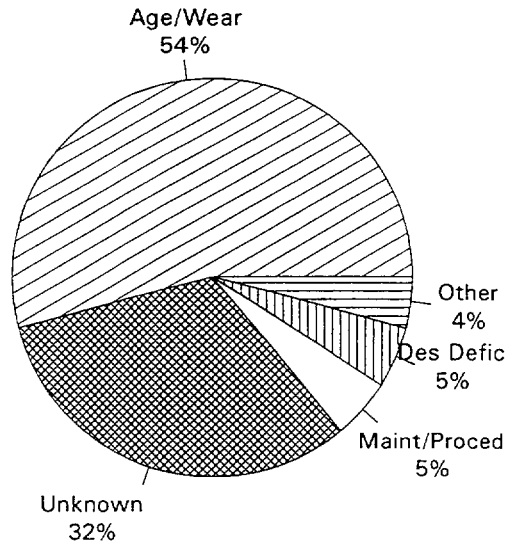
No. of AOV Assy failures: 49

**PWR RI SYSTEMS AOV ASSEMBLIES
VALVE BODY SUBCOMPONENTS**



No. of AOV valve body failures: 12

**PWR RI SYSTEMS AOV ASSEMBLIES
VALVE OPERATOR SUBCOMPONENTS**



No. of AOV valve operator failures: 37

**PWR AOV FAILURE CAUSES
FIGURE 9**

4.4 Related Issues

Generic Letters, Generic Safety Issues, and Information Notices

The review of NRC regulatory initiatives related to AOV assemblies and their subcomponents included Generic Letters (GLs), Circulars, Bulletins, and Information Notices (INs) was performed for the 1987-1998 period. There were no Circulars or Bulletins involving AOVs for this period. There were no AOV failures reported by LERs associated with Generic Letters or Information Notices that were within the scope of the failure population used in this study. Briefly, this report's scope was limited to Application Coded AOVs in PWR and BWR RI systems that failed completely (catastrophically) with "failure-to-open," "failure-to-close," or "failure-to-operate as required" failure modes, and occurred during ESF actuations or surveillance tests.

Other AOV inoperabilities or potential failures that were reported by LERs, applicable to GLs and INs in the study period, were outside the scope of this study. Table D lists the Generic Letters, Generic Safety Issues, and Information Notices applicable to AOV assemblies and their subcomponents.

TABLE D
NRC GENERIC LETTERS (GLs), GENERIC SAFETY ISSUES
AND INFORMATION NOTICES (INs) CONCERNING AOV ASSEMBLIES - 1987-1998

Generic Letters:

GL 91-19 Operating Experience Feedback Report, Solenoid-Operated Valve Problems at U.S. Reactors, September 23, 1991.

Generic Safety

Issue NRC Regulatory Issue Summary 2000-03, Resolution of Generic Safety Issue 158: Performance of Safety-Related Power-Operated Valves Under Design Basis Conditions, March 15, 2000

Information Notices:

IN 87-38 Inadequate or Inadvertent Blocking of Valve Movements, August 17, 1987
IN 88-24 Failures of Air-Operated Valves Affecting Safety-Related Systems, May 13, 1988
IN 89-28 Weight and Center of Gravity Discrepancies for Copes-Vulcan Air-Operated Valves, March 14, 1989
IN 90-17 Weight and Center of Gravity Discrepancies for Copes-Vulcan Air-Operated Valves, March 8, 1990
IN 96-68 Incorrect Effective Diaphragm Area Values in Vendor Manual Result in Potential Failure of Pneumatic Diaphragm Actuators, December 19, 1996

NUREG-1275, Vol. 13 Comparison

In February 2000, NUREG-1275, Vol. 13, "Evaluation of Air-Operated Valves at U.S. Light-Water Reactors" (Ref. 8) was issued. That report raised concerns about the potential occurrence of AOV common cause failures that could disable redundant trains of a safety system. In particular, the possibility of AOV failures from accident or transient conditions (pressure, temperature, flow), air system contamination, or from fabrication and maintenance activities was identified.

There are differences in the evaluation methods between this study and the previously published NUREG-1275, Vol. 13. These differences are in scope, data sources, AOV boundaries, single failure and common cause failure (CCF) definitions, and results from feedback of operating experience. The AOV scope in this study excludes main steam isolation valves (MSIVs), pressurizer power-operated relief valves (PORVs), and the instrument air system and its components (such as air regulators, valves, airlines, and backup accumulators). The failures counted in this report are actual and complete. This report's data set did not include degradations where the AOVs were still functional, nor the potential for failure where additional adverse conditions and/or personnel errors outside the component boundary were identified as a possibility, but did not actually occur.

A review of common cause failure (CCF) database (See Section 3.2) was also performed. This database uses the four criteria in NUREG/CR-6268, Vol. 3, "Common-Cause Failure Database and Analysis System: Data Collection and Event Coding" (June 1998)(Ref. 10). It includes actual complete multiple failures or observed degradations affecting multiple components. Potential failures and degraded conditions in single failures are excluded from this database because of their lower safety significance. NUREG/CR-6268 is widely accepted as the definitive approach to assessing which failures constitute the risk-significant CCF events among all the component failures that occur.

A broader definition of "CCF conditions" was used in NUREG-1275, Vol. 13 wherein the possibility for CCF was identified. For example, it identified AOV air quality as a possible failure mechanism, but only single valve failures were identified. The likelihood and risk significance of these possible conditions was not estimated. The likelihood and the risk significance of such possible failure mechanisms is clearly less than that associated with events where multiple AOVs have actually failed. No events were identified in this NUREG-1715, Vol. 3 report where multiple AOVs failed due to these actual or potential adverse external factors. Thus, the NUREG-1275, Vol. 13 definitions incorporate many events that are of lesser risk significance and are not typically included in the component reliability estimates used in risk analyses. In this NUREG-1715, Vol. 3 report the number of CCF events was consistent with expectations based on NUREG/CR-6268 parameters.

Using a more risk-based approach, and considering actual AOV failures resulting from surveillance testing and engineered safety features (ESF) actuation, this study found consistency with NUREG/CR-4550 generic values for probability of failure on demand and with plant IPE mean values for AOVs. No indications of increased failure rates due to "aging" concerns were found. No evidence of increased CCF susceptibility was found. An earlier report, NUREG/CR-6644, "Generic Issue 158: Performance of Safety-Related Power-Operated Valves Under Operating Conditions" (September 1999)(Ref. 9), also identified that the total number of AOV failure events (with failure modes: failure-to-open, failure-to-close, and failure-to-operate as required) was decreasing with time. A specific review of the 5 AOV events from the NUREG-1275, Vol.13 report that identified differential pressure design inadequacies found that they did not meet the criteria for being Accident Sequence Precursors.

Therefore, all risk-significant AOV events and issues from NUREG/CR-1275, Vol. 13 that were within the scope of this study have been analyzed.

Industry and Other NRC Initiatives

During the time period of this report, one major NRC initiative was undertaken, the Maintenance Rule (implemented in 1995 in most nuclear power plants). Industry initiatives were the AOV Users Group efforts starting in the mid-1990s, that eventually developed into the AOV joint owners group (JOG) program in 1999. While this report shows a decrease in the number of failures per year for AOVs in PWR RI systems, it is not possible to directly attribute improved performance to these initiatives. This is due in part, to the fact that these initiatives were begun near the end of the period. These initiatives also address design-basis capability and other issues in addition to the risk-significant function reliability, estimated in this report. Therefore, it is difficult to establish a cause and effect relationship between the specific activities and the improved AOV performance.

5. SUMMARY OF RESULTS

5.1 Failure Probabilities

For the PWR and BWR RI systems, the AOV estimated probability of failure on demand distributions were consistent with the generic value range from NUREG/CR-4550 (used as an input to NUREG-1150, although the PWR RHR system mean value ($5.2E-4$) is about a factor of 4 lower than the generic mean value ($2E-3$).

The AOV mean probabilities of failure on demand used in plant-specific IPE studies were compared with the results of this study. The PWR IPE mean

values were generally consistent with the results of this study and the NUREG/CR-4550 generic values. No comparison was made with BWR IPE values, as few BWR plants IPEs provided failure probabilities on demand.

5.2 Engineering Insights

The engineering insights gained from this study are summarized as follows:

- For the PWR RI systems during the 1987–1995 period, there was a statistically significant decreasing failure trend. For BWR RI systems, no statistically significant trend was identified. Both the maintenance rule and voluntary industry joint owners group initiatives were begun during this period. While there was insufficient information available to conclude whether these initiatives caused the trend, an improvement in performance had occurred.
- The analysis of failure rates, as a function of component-years, showed no significant variance among the PWR plant age groups (3 groups, of approximately equal size, from older to newer plants by commercial operations date). The review of plant age groups did not show evidence of an increase in failure rates for any plant age groups due to aging mechanisms. For BWRs, failure data was too sparse for trending failure rates by plant age groups.
- The number of complete AOV common-cause failures (CCF) identified in this study is consistent with the expected number based on the CCF database parameters for the combined PWR and BWR complete failure population used in this study.
- The valve operator was the biggest contributor to AOV failures (76%). Although valve operators were also the biggest contributors to BWR AOV failure, the number of failures was too sparse to use.
- Failure of AOV assemblies in PWR RI systems were mainly due to age/wear mechanisms (47%).

6. REFERENCES

1. AEOD/C701, "Air System Problems at U.S. Light Water Reactors," March 1987
2. AEOD/E706, "Inadequate Mechanical Blocking of Valves," March 31, 1987
3. NUREG- 1275, Vol. 2, "Operating Experience Feedback Report – Air Systems Problems," December 1987
4. NUREG-1275, Vol. 6, "Operating Experience Feedback Report – Solenoid Valve Problems," February 1991
5. NUREG/CR-5497 (INEEL/EXT-97-01328), "Common Cause Failure Parameter Estimates," October 1998
6. NUREG/CR-5500, Vol. 1, "Reliability Study: Auxiliary/Emergency Feedwater System, 1987–1995," August 1998
7. NUREG/CR-5500, Vol. 9 (INEEL/EXT-99-00373), "High Pressure Safety Injection System Reliability, 1987–1997," October 2000
8. NUREG-1275, Vol. 13, "Evaluation of Air–Operated Valves at U.S. Light Water Reactors," February 2000
9. NUREG/CR-6644 (INEL - 95/0550), "Generic Issue 158: Performance of Safety-Related Power-Operated Valves Under Operating Conditions," September 1999
10. NUREG/CR-6268, Vol. 3 (INEEL/EXT-97-00696), "Common-Cause Failure Database and Analysis System: Data Collection and Event Coding," June 1998
11. Harry F.Martz and Ray A. Waller, Bayesian Reliability Analysis, Krieger, Section 7.6, Malabar, FL, 1991.
12. NUREG/CR-4550, SAND86-2084, "Analysis of Core Damage Frequency Internal Events Methodology," Vol. 1, Rev. 1, January 1990

APPENDIX I
AOV ASSEMBLY
FAILURE PROBABILITIES

APPENDIX I - AOV ASSEMBLY FAILURE PROBABILITIES

<u>TABLE NO.</u>	<u>DESCRIPTION</u>	<u>PAGE</u>
I	PWR RI Systems AOV Assemblies Probability of Failure on Demand	I-2
II	BWR RI Systems AOV Assemblies Probability of Failure on Demand	I-3

APPENDIX I - TABLE I
PWR RI SYSTEM AOV ASSEMBLIES
PROBABILITY OF FAILURE ON DEMAND

		PROBABILITY OF FAILURE ON DEMAND								
	NO. FAIL.	NO. DEMD	90% CONFID. INTERVALS			BAYES 90% INTERVALS			PRIOR	
			PLCB	PHAT	PUCB	PLO	MEAN	PUP	A	B
AFW	13	8547	9.1E-4	1.5E-3	2.4E-3	4.6E-6	1.8E-3	6.9E-3	0.4646	263.37
HPI	0	409	-	-	-	4.8E-6	1.2E-3	4.7E-3	Noninformative	
RHR	1	2889	1.8E-5	3.5E-4	1.6E-3	6.1E-5	5.2E-4	1.3E-3	Prior	
CVCS	22	7735	1.9E-3	2.8E-3	4.1E-3	3.5E-7	3.4E-3	1.5E-2	Noninformative	
CCW	4	821	1.6E-3	4.9E-3	1.1E-2	6.7E-5	5.8E-3	2.1E-2	Prior	
									0.2991	88.19
									0.6281	107.06

NOTES:

- 1 For the 1987-1995 period, the contingency test accepted the hypothesis that the ESF failures and demands were in the same population as the surveillance test failures and demands for the AFW, CVCS, and RHR systems. Since the contingency test for the 1996-1998 ESF data was also accepted for the AFW, CVCS, and RHR systems, the probability of failure on demand data combined the surveillance test data for 1987-1995 with ESF data for 1987-1998.
- 2 For the 1987-1995 period, the contingency test rejected the hypothesis that the ESF failures and demands were in the same population as the surveillance test failures and demands for the HPI and CCW systems. There was no ESF data (failures or demands) for the CCW system. The surveillance test data (1987-1995) was used for estimating the probability of failure on demand for these two systems.
- 3 The 90% confidence intervals (chi-square) are provided for information. The Bayes 90% intervals are used in this study for RI system estimated probability of failure on demand.

APPENDIX I - TABLE II
BWR RI SYSTEMS AOV ASSEMBLIES
PROBABILITY OF FAILURE ON DEMAND

PROBABILITY OF FAILURE ON DEMAND										
	NO. FAIL.	NO. DEMD	90% CONFID. INTERVALS			BAYES 90% INTERVALS			PRIOR	
			PLCB	PHAT	PUCB	PLO	MEAN	PUP	A	B
RCIC	1	507	1.0E-4	2.0E-3	9.3E-3	3.5E-4	3.0E-4	7.7E-3	Noninformative Prior	
HPCI	1	409	1.2E-4	2.4E-3	1.1E-2	4.3E-4	3.6E-3	9.5E-3	Noninformative Prior	
LPCS	4	1758	7.8E-4	2.3E-3	5.2E-3	2.9E-15	2.1E-3	1.2E-2	0.1031	50.02

NOTES:

- 1 For the 1987–1995 period, the contingency test accepted the hypothesis that the ESF failures and demands were in the same population as the surveillance test failures and demands for the listed systems. Since the contingency test for the 1996–1998 ESF data was also accepted, the probability of failure on demand data combined the surveillance test data for 1987–1995 with ESF data for 1987–1998.
- 2 The 90% confidence intervals (chi-square) are provided for information. The Bayes 90% intervals are used in this study for RI system estimated probability of failure on demand.

APPENDIX II
AOV ASSEMBLY
COMPONENT TRENDS IN TIME

APPENDIX II
AOV ASSEMBLY COMPONENT TRENDS IN TIME

<u>TABLE NO.</u>	<u>DESCRIPTION</u>	<u>PAGE</u>
I	PWR RI Systems AOV Assembly Failures Versus Component- Years – Plant Age Group A– ESF and Surveillance Test Failures – 1987–1995	II-2
II	PWR RI Systems AOV Assembly Failures Versus Component- Years – Plant Age Group B – ESF and Surveillance Test Failures – 1987–1995	II-3
III	PWR RI Systems AOV Assembly Failures Versus Component- Years – Plant Age Group C – ESF and Surveillance Test Failures – 1987–1995	II-4

APPENDIX II - TABLE I
PWR RI SYSTEMS AOV ASSEMBLY FAILURES VERSUS COMPONENT-YEARS
PLANT AGE GROUP A
ESF AND SURVEILLANCE TEST FAILURES - 1987-1995

<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>FAIL.</u>	<u>CUMULATIVE</u> <u>AOV-YEARS</u>	<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>FAIL.</u>	<u>CUMULATIVE</u> <u>AOV-YEARS</u>	<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>FAIL.</u>	<u>CUMULATIVE</u> <u>AOV-YEARS</u>
1/87	0	27	1/90	0	1008	1/93	0	1989
2/87	1	54	2/90	0	1036	2/93	1	2016
3/87	0	82	3/90	0	1063	3/93	0	2044
4/87	0	109	4/90	1	1090	4/93	0	2071
5/87	1	136	5/90	0	1117	5/93	0	2098
6/87	0	164	6/90	0	1145	6/93	0	2126
7/87	0	191	7/90	0	1172	7/93	0	2153
8/87	0	218	8/90	0	1199	8/93	0	2180
9/87	0	245	9/90	0	1226	9/93	0	2207
10/87	0	272	10/90	0	1254	10/93	0	2234
11/87	2	300	11/90	0	1281	11/93	0	2262
12/87	0	327	12/90	0	1308	12/93	0	2289
1/88	0	354	1/91	0	1335	1/94	0	2316
2/88	0	382	2/91	0	1362	2/94	0	2344
3/88	0	409	3/91	0	1390	3/94	0	2371
4/88	0	436	4/91	0	1417	4/94	0	2398
5/88	0	463	5/91	0	1444	5/94	0	2425
6/88	0	491	6/91	0	<u>1472 - L/2</u>	6/94	0	2452
7/88	0	518	7/91	0	1499	7/94	0	2480
8/88	0	545	8/91	0	1526	8/94	0	2507
9/88	0	572	9/91	0	1553	9/94	0	2534
10/88	0	600	10/91	0	1581	10/94	0	2562
11/88	0	627	11/91	0	1608	11/94	0	2589
12/88	0	654	12/91	0	1635	12/94	0	2616
1/89	1	681	1/92	0	1662	1/95	0	2644
2/89	0	708	2/92	0	1690	2/95	2	2671
3/89	0	736	3/92	0	1717	3/95	0	2698
4/89	0	763	4/92	0	1744	4/95	0	2725
5/89	0	790	5/92	2	1771	5/95	0	2752
6/89	0	818	6/92	1	1798	6/95	0	2780
7/89	0	845	7/92	0	1826	7/95	0	2807
8/89	0	872	8/92	0	1853	8/95	0	2834
9/89	0	899	9/92	0	1880	9/95	0	2861
10/89	0	926	10/92	0	1908	10/95	1	2889
11/89	2	954	11/92	0	1935	11/95	0	2916
12/89	0	981	12/92	0	1962	12/95	0	2943
Totals:							15	

NOTES:

1. $\lambda_{AVE} = \frac{15}{2943} = 0.005$ failures per component-year (1987-1995).
2. The mean time between failures = $1/0.005 = 200$ component-years.
3. Failures are for the PWR RI systems in plant age group A.
4. L/2 indicates the midpoint of the cumulative AOV-years for the 1987-1995 period, for use in the Laplace test (see Section 4.2 in the text).
5. See Figure 7 in the text.

APPENDIX II - TABLE II
PWR RI SYSTEMS AOV ASSEMBLY FAILURES VERSUS COMPONENT-YEARS
PLANT AGE GROUP B
ESF AND SURVEILLANCE TEST FAILURES - 1987-1995

<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>FAIL.</u>	<u>CUMULATIVE</u> <u>AOV-YEARS</u>	<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>FAIL.</u>	<u>CUMULATIVE</u> <u>AOV-YEARS</u>	<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>FAIL.</u>	<u>CUMULATIVE</u> <u>AOV-YEARS</u>
1/87	0	39	1/90	0	1437	1/93	0	2835
2/87	0	77	2/90	0	1476	2/93	0	2874
3/87	1	116	3/90	0	1514	3/93	0	2912
4/87	0	155	4/90	0	1553	4/93	0	2951
5/87	0	194	5/90	1	1592	5/93	0	2990
6/87	1	233	6/90	0	1631	6/93	0	3029
7/87	2	272	7/90	1	1670	7/93	0	3068
8/87	0	311	8/90	0	1709	8/93	1	3107
9/87	0	349	9/90	0	1747	9/93	0	3145
10/87	0	388	10/90	0	1786	10/93	0	3184
11/87	0	427	11/90	0	1825	11/93	0	3223
12/87	2	466	12/90	0	1864	12/93	0	3262
1/88	0	505	1/91	0	1903	1/94	0	3301
2/88	0	544	2/91	0	1942	2/94	0	3340
3/88	0	582	3/91	0	1980	3/94	0	3378
4/88	0	621	4/91	0	2019	4/94	0	3417
5/88	0	660	5/91	0	2058	5/94	0	3456
6/88	0	699	6/91	0	2097 - L/2	6/94	0	3495
7/88	0	738	7/91	0	2136	7/94	0	3534
8/88	0	777	8/91	0	2175	8/94	0	3573
9/88	1	815	9/91	0	2214	9/94	0	3611
10/88	0	854	10/91	0	2252	10/94	0	3650
11/88	0	893	11/91	0	2291	11/94	0	3689
12/88	0	932	12/91	0	2330	12/94	0	3728
1/89	0	971	1/92	0	2369	1/95	0	3767
2/89	1	1010	2/92	0	2408	2/95	0	3806
3/89	1	1048	3/92	0	2446	3/95	0	3844
4/89	0	1087	4/92	0	2485	4/95	0	3883
5/89	0	1126	5/92	0	2524	5/95	0	3922
6/89	0	1164	6/92	0	2563	6/95	0	3961
7/89	0	1203	7/92	0	2602	7/95	0	4000
8/89	0	1242	8/92	0	2641	8/95	0	4039
9/89	0	1281	9/92	2	2679	9/95	0	4077
10/89	1	1320	10/92	1	2718	10/95	0	4116
11/89	0	1359	11/92	0	2757	11/95	0	4155
12/89	0	1398	12/92	1	2796	12/95	1	4194
Totals:							18	

NOTES:

1. $\lambda_{AVE} = \frac{18}{4194} = 0.004$ failures per component-year (1987-1995).
2. The mean time between failures = $1/0.004 = 250$ component-years.
3. Failures are for the PWR RI systems in plant age group B.
4. L/2 indicates the midpoint of the cumulative AOV-years for the 1987-1995 period, for use in the Laplace test (see Section 4.2 in the text).
5. See Figure 7 in the text.

APPENDIX II - TABLE III
PWR RI SYSTEMS AOV ASSEMBLY FAILURES VERSUS COMPONENT-YEARS
PLANT AGE GROUP C
ESF AND SURVEILLANCE TEST FAILURES – 1987–1995

<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>FAIL.</u>	<u>CUMULATIVE</u> <u>AOV-YEARS</u>	<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>FAIL.</u>	<u>CUMULATIVE</u> <u>AOV-YEARS</u>	<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>FAIL.</u>	<u>CUMULATIVE</u> <u>AOV-YEARS</u>
1/87	0	15	1/90	1	707	1/93	0	1650
2/87	0	31	2/90	0	731	2/93	0	1678
3/87	0	46	3/90	1	754	3/93	0	1705
4/87	0	61	4/90	1	778	4/93	0	1732
5/87	0	77	5/90	0	802	5/93	0	1759
6/87	0	92	6/90	0	826	6/93	0	1786
7/87	0	107	7/90	0	850	7/93	0	1814
8/87	0	123	8/90	0	874	8/93	0	1841
9/87	0	138	9/90	0	897	9/93	0	1868
10/87	0	153	10/90	0	921	10/93	0	1896
11/87	0	169	11/90	1	945	11/93	0	1923
12/87	0	184	12/90	0	969	12/93	1	1950
1/88	0	204	1/91	0	996	1/94	0	1977
2/88	0	224	2/91	0	1024	2/94	0	2004
3/88	0	244	3/91	0	1051	3/94	0	2032
4/88	0	264	4/91	0	1078	4/94	0	2059
5/88	0	284	5/91	0	1105	5/94	0	2086
6/88	0	304	6/91	0	1132	6/94	1	2114
7/88	0	323	7/91	0	1160	7/94	0	2141
8/88	0	343	8/91	0	1187	8/94	0	2168
9/88	0	363	9/91	1	1214	9/94	0	2195
10/88	1	383	10/91	0	1242	10/94	0	2223
11/88	0	403	11/91	0	1269	11/94	0	2250
12/88	0	423	12/91	1	1296	12/94	0	2277
1/89	1	445	1/92	0	1323	1/95	0	2304
2/89	0	466	2/92	0	1351	2/95	0	2332
3/89	0	488	3/92	0	1378	3/95	0	2359
4/89	0	510	4/92	0	1405	4/95	0	2386
5/89	0	531	5/92	0	1432	5/95	0	2413
6/89	1	553	6/92	0	1459	6/95	0	2441
7/89	0	575	7/92	0	1487	7/95	0	2468
8/89	0	596	8/92	2	1514	8/95	0	2495
9/89	0	618	9/92	0	1541	9/95	1	2522
10/89	0	640	10/92	0	1568	10/95	1	2550
11/89	1	661	11/92	0	1596	11/95	0	2577
12/89	0	683	12/92	0	1623	12/95	0	2604
Totals:							16	

NOTES:

1. $\lambda_{AVE} = \frac{16}{2604} = 0.006$ failures per component-year 1987–1995).
2. The mean time between failures = $1/0.006 = 167$ component-years.
3. Failures are for the PWR RI systems in plant age group C.
4. $L/2$ indicates the midpoint of the cumulative AOV-years for the 1987–1995 period, for use in the Laplace test (see Section 4.2 in the text).
5. See Figure 7 in the text.

APPENDIX III

AOV ASSEMBLY

ENGINEERING INSIGHTS ON REPORTED FAILURES

APPENDIX III
AOV ASSEMBLY – ENGINEERING INSIGHTS ON REPORTED FAILURES

<u>TABLE NO.</u>	<u>DESCRIPTION</u>	<u>PAGE</u>
I	Selected PWR RI Systems – Failures Per Component For Application Coded AOV Subcomponents and Assemblies	III-2
II	Selected BWR RI Systems – Failures Per Component For Application Coded AOV Subcomponents and Assemblies	III-3
III	Selected PWR and BWR RI Systems – Subcomponent Parts Failure Apportionment	III-4
IV	Selected PWR and BWR RI Systems – Subcomponent Parts Failure Causes Apportionment	III-5

APPENDIX III – TABLE I
SELECTED PWR RI SYSTEMS – FAILURES PER COMPONENT FOR APPLICATION CODED AOV
SUBCOMPONENTS AND ASSEMBLIES

<u>VALVE BODIES</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>TOTAL</u>
No. Surv. Test Fail.	0	1	1	1	0	2	1	0	3	9
No. ESF Failures	3	0	0	0	0	0	0	0	0	3
Total No. Failures	3	1	1	1	0	2	1	0	3	12
No. Valve Bodies	977	1032	1053	1053	1120	1120	1120	1120	1120	
Failures Per Comp-Yr	.003	.001	.001	.001	0	.002	.001	0	.003	
Ave. Fail. Per Comp.	-----.001-----									
<u>VALVE OPERATORS</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>TOTAL</u>
No. Surv. Test Fail.	5	0	8	6	0	7	2	1	3	32
No. ESF Failures	2	1	0	0	2	0	0	0	0	5
Total No. Failures	7	1	8	6	2	7	2	1	3	37
No. Valve Oper.	977	1032	1053	1053	1120	1120	1120	1120	1120	
Failures Per Comp-Yr	.007	.001	.008	.006	.002	.006	.002	.001	.003	
Ave. Fail. Per Comp.	-----.004-----									
<u>AOV ASSY</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>TOTAL</u>
Total No. Failures	10	2	9	7	2	9	3	1	6	49
No. AOV Assys	977	1032	1053	1053	1120	1120	1120	1120	1120	
Failures Per Comp-Yr	.010	.002	.008	.007	.002	.008	.003	.001	.005	
Ave. Failures Per Comp.	-----.005-----									

Note 1. See Figure 6 in text.

APPENDIX III - TABLE II
SELECTED BWR RI SYSTEMS - FAILURES PER COMPONENT FOR APPLICATION CODED AOV
SUBCOMPONENTS AND ASSEMBLIES

<u>VALVE BODIES</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>TOTAL</u>
No. Surv. Test Fail.:	0	0	0	0	2	0	0	0	0	2
No. ESF Failures:	0	0	0	0	0	0	0	0	0	0
Total No. Failures:	0	0	0	0	2	0	0	0	0	2
No. Valve Bodies:	102	107	107	109	109	109	109	109	109	
Failures Per Comp-Yr	0	0	0	0	.018	0	.0	0	0	
Ave. Fail. Per Comp.	-----.002-----									
<u>VALVE OPERATORS</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>TOTAL</u>
No. Surv. Test Fail.:	0	1	0	2	0	1	0	0	0	4
No. ESF Failures:	0	0	0	0	0	0	0	0	0	0
Total No. Failures:	0	1	0	2	0	1	0	0	0	4
No. Valve Oper.	102	107	107	109	109	109	109	109	109	
Failures Per Comp-Yr	0	.009	0	.018	0	.009	0	0	0	
Ave. Fail. Per Comp.	-----.004-----									
<u>AOV ASSY</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>TOTAL</u>
Total No. Failures:	0	1	0	2	2	1	0	0	0	6
No. AOV Assys:	102	107	107	109	109	109	109	109	109	
Failures Per Comp-Yr	0	.009	0	.018	.018	.009	0	0	0	
Ave. Failures Per Comp.	-----.006-----									

Notes:

1. No figure is provided in the text, as failure data is too sparse.

APPENDIX III – TABLE III
SELECTED PWR AND BWR RI SYSTEMS – SUBCOMPONENT PARTS
FAILURE APPORTIONMENT

A. Valve Bodies

<u>PWR</u>			<u>BWR</u>		
<u>Subcomp. Part</u>	<u>No. Fail.</u>	<u>Percent</u>	<u>Subcomp. Part</u>	<u>No. Fail.</u>	<u>Percent</u>
Valve Internals	6	50	Valve Internals	1	50
Valve Stem	4	33	Valve Stem	0	0
Packing	<u>2</u>	<u>17</u>	Packing	<u>1</u>	<u>50</u>
Totals:	12	100	Totals:	2	100

B. Valve Operators

<u>PWR</u>			<u>BWR</u>		
<u>Subcomp. Part</u>	<u>No. Fail.</u>	<u>Percent</u>	<u>Subcomp. Part</u>	<u>No. Fail.</u>	<u>Percent</u>
Solenoid Valve	9	24	Solenoid Valves	4	100
Diaphragm	3	8	Diaphragms	0	0
Internals	5	14	Internals	0	0
Positioner	5	14	Positioner	0	0
Air Regulator	6	16	Air Regulator	0	0
Air Line	3	8	Air Line	0	0
Other	<u>6</u>	<u>16</u>	Other	<u>0</u>	<u>0</u>
Totals:	37	100	Totals:	4	100

Notes:

1. See Figure 8 in text for PWRs.
2. No figure is provided in text for BWRs, as data is too sparse.

APPENDIX III – TABLE IV
SELECTED PWR AND BWR RI SYSTEMS – SUBCOMPONENT PARTS
FAILURE CAUSES APPORTIONMENT

A. Valve Bodies

<u>PWR</u>			<u>BWR</u>		
<u>Fail. Cause</u>	<u>No. Fail.</u>	<u>Percent</u>	<u>Failure Cause</u>	<u>No. Fail.</u>	<u>Percent</u>
Age/Wear	3	25	Age/Wear	1	50
Unknown	1	8	Unknown	0	0
Dirt/Contam./ Corrosion	1	8	Dirt/Contam./ Corrosion	0	0
Maint./Proced. Deficiencies	4	34	Maint./Proced. Deficiencies	1	50
Debris/Foreign Material	2	17	Debris/Foreign Material	0	0
Design Defic.	<u>1</u>	<u>8</u>	Design Defic.	<u>0</u>	<u>0</u>
Totals:	12	100	Totals:	2	100

B. Valve Operators

<u>PWR</u>			<u>BWR</u>		
<u>Fail. Cause</u>	<u>No. Fail.</u>	<u>Percent</u>	<u>Failure Cause</u>	<u>No. Fail.</u>	<u>Percent</u>
Age/Wear	20	54	Age/Wear.	4	100
Unknown	12	33	Unknown	0	0
Dirt/Contam./ Corrosion	0	0	Dirt/Contam./ Corrosion	0	0
Maint./Proced. Deficiencies	2	5	Maint./Proced. Deficiencies	0	0
Design Defic.	2	5	Design Defic.	0	0
Other	<u>1</u>	<u>3</u>	Other	<u>0</u>	<u>0</u>
Totals:	37	100	Totals:	4	100

Notes:

1. See Figure 9 in text for PWRs.
2. No figure is provided in text for BWRs, as failure data is too sparse.

APPENDIX IV

AOV ASSEMBLY

DATA SOURCE INPUT FOR REPORTED FAILURES AND ESTIMATED DEMANDS

ABBREVIATIONS USED IN APPENDIX IV - TABLES I THROUGH IV

Column Headings:

ESF/SURV -	ESF or surveillance test failure																						
PLT ID NO. -	Numerical identifier assigned to each selected plant used with NPRDS failure histories. When source is from LERs, a 3-digit docket number is used.																						
DATA SRC -	Data Source, either as NPRDS failure history (FHIS) or as a 5-digit LER number, as applicable.																						
PLT AGE -	Plant Age Group (A, B, or C) that indicates the plant commercial license date as follows:																						
	A - 12/31/74 and earlier.	B - 1/1/75 through 3/31/86 C - 4/1/86 and later																					
PLT SYS -	The selected risk important (RI) system in which the component failed (see text list of acronyms for system abbreviations).																						
NO. FAIL -	Number of same subcomponents failed with same failure mode, system, date, etc.																						
DISC DATE -	For NPRDS failures, this is the discovery date and for LERs, this is the event date, shown by month and year only (i.e., 0189 is January 1989, etc.).																						
SUB COMP -	Subcomponent of the AOV assembly (VB - Valve Body and VO - Valve Operator).																						
COMP PART -	Subcomponent part. These are as follows: <table> <tr> <th><u>Valve Bodies (VB)</u></th><th colspan="2"><u>Valve Operators (VO)</u></th></tr> <tr> <td>Internals (INT)</td><td>Internals/seals (INT)</td><td>Solenoid valve (SOV)</td></tr> <tr> <td>Packing (PKG)</td><td>Diaphragm (DIA)</td><td>Air line (AL)</td></tr> <tr> <td>Stem (STM)</td><td>Air Regulator (AR)</td><td>Pilot Valve (PV)</td></tr> <tr> <td></td><td>Volume Booster (VOL)</td><td>Positioner (POS)</td></tr> <tr> <td></td><td>Wiring/Contacts (WC)</td><td>Bolting (BLT)</td></tr> <tr> <td></td><td>Mechanical Linkage (ML)</td><td></td></tr> </table>		<u>Valve Bodies (VB)</u>	<u>Valve Operators (VO)</u>		Internals (INT)	Internals/seals (INT)	Solenoid valve (SOV)	Packing (PKG)	Diaphragm (DIA)	Air line (AL)	Stem (STM)	Air Regulator (AR)	Pilot Valve (PV)		Volume Booster (VOL)	Positioner (POS)		Wiring/Contacts (WC)	Bolting (BLT)		Mechanical Linkage (ML)	
<u>Valve Bodies (VB)</u>	<u>Valve Operators (VO)</u>																						
Internals (INT)	Internals/seals (INT)	Solenoid valve (SOV)																					
Packing (PKG)	Diaphragm (DIA)	Air line (AL)																					
Stem (STM)	Air Regulator (AR)	Pilot Valve (PV)																					
	Volume Booster (VOL)	Positioner (POS)																					
	Wiring/Contacts (WC)	Bolting (BLT)																					
	Mechanical Linkage (ML)																						
FAIL MODE -	Failure Mode as follows: Failure to close (FC) Failure to open (FO) Failure to operate as required (both fail to open and fail to close - OR)																						
FAIL CAUS -	Failure cause as follows: <table> <tr> <td>Age/Wear (AW)</td><td>Dirt/Contamination (DC)</td><td>Other Devices (OD)</td></tr> <tr> <td>Design Deficiency (DD)</td><td>Manufacturing Defect (MF)</td><td></td></tr> <tr> <td>Unknown (UK)</td><td>Debris/Foreign Material (DF)</td><td></td></tr> <tr> <td>Maintenance/Procedural Deficiency (MP)</td><td></td><td></td></tr> </table>		Age/Wear (AW)	Dirt/Contamination (DC)	Other Devices (OD)	Design Deficiency (DD)	Manufacturing Defect (MF)		Unknown (UK)	Debris/Foreign Material (DF)		Maintenance/Procedural Deficiency (MP)											
Age/Wear (AW)	Dirt/Contamination (DC)	Other Devices (OD)																					
Design Deficiency (DD)	Manufacturing Defect (MF)																						
Unknown (UK)	Debris/Foreign Material (DF)																						
Maintenance/Procedural Deficiency (MP)																							

APPENDIX IV
DATA SOURCE INPUT FOR REPORTED FAILURES AND ESTIMATED DEMANDS
LIST OF TABLES

<u>TABLE NO.</u>	<u>DESCRIPTION</u>	<u>PAGE</u>
I	PWR AOV Assemblies – Selected RI Systems Data Source Inputs – Surveillance Test and ESF Failures – 1987–1995	IV-3
II	BWR AOV Assemblies – Selected RI Systems Data Source Inputs – Surveillance Test and ESF Failures – 1987–1995	IV-5
III	PWR Application Coded AOV Assemblies – Selected RI System Data Source Inputs – ESF Demands – 1987–1995	IV-6
IIIA	PWR Application Coded AOV Assemblies - Selected RI System Data Source Inputs - ESF Demands - 1996-1998	IV-15
IV	BWR Application Coded AOV Assemblies – Selected RI System Data Source Inputs – ESF Demands – 1987–1995	IV-16
IVA	BWR Application Coded AOV Assemblies – Selected RI System Data Source Inputs – ESF Demands – 1996–1998	IV-17
V	PWR Application Coded AOV Assemblies – Selected RI System Data Source Inputs – Estimated Surveillance Test Demands – 1987–1995	IV-18
VI	BWR Application Coded AOV Assemblies – Selected RI System Data Source Inputs – Estimated Surveillance Test Demands – 1987–1995	IV-29

APPENDIX IV - TABLE I
PWR AOV ASSEMBLIES - SELECTED RI SYSTEMS DATA SOURCE INPUTS
SURVEILLANCE TEST AND ESF FAILURES 1987-1995

ITEM NO.	ESF/ SURV	PLT ID NO.	DATA SRC.	PLT AGE	PLT SYS	NO. FAIL	DISC DATE	SUB COMP	COMP PART	FAIL MODE	FAIL CAUS
1	SURV	11	FHIS	A	AFW	1	0287	VO	AR	OR	UK
2	SURV	46	FHIS	B	AFW	1	0387	VO	WC	FC	UK
3	ESF	13	FHIS	A	RCS	1	0587	VB	STM	FC	MP
4	SURV	83	FHIS	B	CVCS	1	0687	VO	AR	FO	AW
5	ESF	336	87011	B	RCS	2	0787	VB	PKG	FC	AW
6	ESF	266	87005	A	RCS	1	1187	VO	POS	FC	AW
7	SURV	11	FHIS	A	AFW	1	1187	VO	POS	FO	UK
8	ESF	65	FHIS	B	CVCS	1	1287	VO	SOV	OR	AW
9	SURV	72	FHIS	B	AFW	1	1287	VO	SOV	FO	UK
10	ESF	334	88014	B	AFW	1	0988	VO	DIA	FC	AW
11	SURV	79	FHIS	C	CVCS	1	1088	VB	INT	FC	DD
12	SURV	40	FHIS	A	CCW	1	0189	VO	ART	FO	AW
13	SURV	88	FHIS	C	CVCS	1	0189	VO	SOV	FO	UK
14	SURV	83	FHIS	B	CVCS	1	0289	VB	INT	FO	UK
15	SURV	83	FHIS	B	CVCS	1	0389	VO	SOV	FC	AW
16	SURV	89	FHIS	C	AFW	1	0689	VO	POS	FC	UK
17	SURV	44	FHIS	B	RCS	1	1089	VO	AR	FO	AW
18	SURV	27	FHIS	A	CVCS	1	1189	VO	AL	FO	UK
19	SURV	38	FHIS	A	CVCS	1	1189	VO	SOV	OR	AW
20	SURV	85	FHIS	C	CVCS	1	1189	VO	SOV	FO	UK
21	SURV	88	FHIS	C	CVCS	1	0190	VO	INT	FO	AW
22	SURV	88	FHIS	C	CVCS	1	0390	VO	INT	FO	AW
23	SURV	28	FHIS	A	CCW	1	0490	VO	BLT	FO	MP
24	SURV	103	FHIS	C	CVCS	1	0490	VO	SOV	FO	AW
25	SURV	54	FHIS	B	AFW	1	0590	VB	STM	FC	MP
26	SURV	23	FHIS	B	CVCS	1	0790	VO	DIA	FO	AW
27	SURV	85	FHIS	C	CVCS	1	1190	VO	BLT	FO	UK
28	ESF	414	91011	C	RCS	1	0991	VO	POS	FC	DD
29	ESF	499	91010	C	RCS	1	1291	VO	POS	OR	MP

APPENDIX IV - TABLE I (CONTINUED)
PWR AOV ASSEMBLIES - SELECTED RI SYSTEMS DATA SOURCE INPUTS
SURVEILLANCE TEST AND ESF FAILURES 1987-1995

ITEM NO.	APPL CODE	PLT ID NO.	DATA SRC.	PLT AGE	PLT SYS	NO. FAIL	DISC DATE	SUB COMP	COMP PART	FAIL MODE	FAIL CAUS
30	SURV	269	92005	A	AFW	1	0592	VO	SOV	OR	DD
31	SURV	20	FHIS	A	AFW	1	0592	VO	SOV	FC	OD
32	SURV	8	FHIS	A	AFW	1	0692	VB	STM	OR	DC
33	SURV	88	FHIS	C	CVCS	2	0892	VO	INT	FO	AW
34	SURV	59	FHIS	B	CVCS	1	0992	VO	AR	FO	AW
35	SURV	65	FHIS	B	RHR	1	0992	VO	AL	OR	UK
36	SURV	44	FHIS	B	RCS	1	1092	VO	AR	FO	AW
37	SURV	54	FHIS	B	CVCS	1	1292	VB	STM	FC	MP
38	SURV	247	93003	A	CCW	1	0293	VB	INT	FC	AW
39	SURV	55	FHIS	B	AFW	1	0893	VO	DIA	FC	AW
40	SURV	88	FHIS	C	CVCS	1	1293	VO	INT	FO	AW
41	SURV	103	FHIS	C	CVCS	1	0694	VO	ML	FO	UK
42	SURV	2	FHIS	A	CCW	1	0295	VB	INT	FC	DF
43	SURV	28	FHIS	A	CVCS	1	0295	VB	INT	FC	MP
44	SURV	85	FHIS	C	CVCS	1	0995	VO	AL	FO	AW
45	SURV	8	FHIS	A	AFW	1	1095	VB	INT	FO	DF
46	SURV	24	FHIS	C	RCS	1	1095	VO	VOL	OR	UK
47	SURV	54	FHIS	B	AFW	1	1295	VO	PV	OR	AW

Total number of PWR AOV failures: 49

Note: There were no PWR AOV ESF failures for the 1996-1998 period.

APPENDIX IV - TABLE II
BWR AOV ASSEMBLIES - SELECTED RI SYSTEMS DATA SOURCE INPUTS
SURVEILLANCE TEST FAILURES 1987-1995

ITE M NO.	APPL CODE	PLT ID NO.	DATA SRC.	PLT AGE	PLT SYS	NO. FAIL	DISC DATE	SUB COMP	COMP PART	FAIL MODE	FAIL CAUS
1	SURV	80	FHIS	B	LPCS	1	0488	VO	SOV	FC	AW
2	SURV	57	FHIS	B	LPCS	1	0490	VO	SOV	FC	AW
3	SURV	57	FHIS	B	LPCS	1	0890	VO	SOV	FC	AW
4	SURV	26	FHIS	B	HPCI	1	0591	VB	INT	FO	AW
5	SURV	84	FHIS	C	RCIC	1	0991	VB	PKG	FC	MP
6	SURV	80	FHIS	B	LPCS	1	0492	VO	SOV	FC	AW

Total number of BWR AOV failures: 6

Note: There were no BWR AOV ESF failures for the 1987-1998 period.

APPENDIX IV - TABLE III
PWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1987-1995

<u>ITEM NO.</u>	<u>DKT NO.</u>	<u>LER NO.</u>	<u>PLANT SYSTEM</u>	<u>EVENT DATE</u>	<u>NO. ESFs</u>	<u>NO. AOVs</u>	<u>NO. AOV DEMANDS</u>
1	247	88019	AFW	1188	1	4	4
2	247	91001	AFW	0191	1	8	8
3	247	92007	AFW	0492	1	4	4
4	247	95001	AFW	0195	1	4	4
5	255	87009	AFW	0387	1	7	7
6	255	87029	AFW	0987	1	5	5
7	255	88006	AFW	0388	1	3	3
8	255	89020	AFW	0889	1	3	3
9	255	90001	AFW	0190	1	3	3
10	255	90002	AFW	0290	1	3	3
11	255	90003	AFW	0390	1	3	3
12	255	90014	AFW	0890	1	3	3
13	255	92034	AFW	0792	1	5	5
14	255	92035	AFW	0792	1	3	3
15	255	92037	AFW	0892	1	5	5
16	255	92039	AFW	1092	1	3	3
17	255	95001	RHR	0395	1	3	3
18	269	88009	AFW	0788	1	4	4
19	269	89001	AFW	0189	1	4	4
20	269	89001	HPI	0189	1	1	1
21	269	89002	AFW	0189	1	4	4
22	269	89002	HPI	0189	1	1	1
23	269	91006	HPI	0591	1	1	1
24	269	91011	AFW	1091	1	4	4
25	269	92004	AFW	0592	1	2	2
26	269	92015	AFW	1092	1	2	2
27	269	93008	AFW	0893	1	2	2
28	269	93008	HPI	0893	1	1	1
29	269	93010	AFW	1193	1	2	2
30	269	93010	HPI	1193	1	1	1
31	269	94002	AFW	0294	1	4	4
32	269	94002	HPI	0294	1	1	1
33	270	87001	HPI	0187	1	1	1
34	270	87002	HPI	0387	1	1	1
35	270	87004	AFW	0487	1	4	4
36	270	89002	HPI	0289	1	1	1
37	270	89003	HPI	0289	1	1	1
38	270	89004	AFW	0489	1	4	4
39	270	92004	AFW	1092	1	4	4
40	270	92004	HPI	1092	1	1	1
41	270	93001	AFW	0493	1	4	4
42	270	93007	HPI	1093	1	1	1
43	270	94002	AFW	0494	1	4	4
44	270	94002	HPI	0494	1	1	1
45	270	94005	AFW	1294	1	4	4
46	270	95002	HPI	0495	1	1	1
47	272	89007	AFW	0289	1	5	5
48	272	89024	CVCS	0689	1	6	6
49	272	89027	AFW	0689	1	5	5
50	272	90030	AFW	0990	1	5	5
51	272	91007	AFW	0291	1	10	10
52	272	91022	AFW	0691	1	3	3
53	272	91024	AFW	0691	1	5	5
54	272	91027	AFW	0891	1	3	3
55	272	93013	AFW	0793	1	5	5

APPENDIX IV - TABLE III (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1987-1995

ITEM	DKT	LER	PLANT	EVENT	NO.	NO.	NO. AOV
NO.	NO.	NO.	SYSTEM	DATE	ESFs	AOVs	DEMANDS
56	272	94007	CVCS	0494	2	6	12
57	272	94011	AFW	0794	1	10	10
58	280	92001	AFW	0192	1	1	1
59	280	93001	AFW	0193	1	1	1
60	280	93002	AFW	0293	1	1	1
61	280	94006	AFW	0594	1	1	1
62	280	95001	AFW	0195	1	1	1
63	280	95003	AFW	0495	1	1	1
64	281	88010	AFW	0190	1	1	1
65	281	89010	AFW	0989	1	1	1
66	281	92010	AFW	0992	1	1	1
67	281	93003	AFW	0893	1	1	1
68	281	93004	AFW	0893	1	1	1
69	281	93005	AFW	0893	1	1	1
70	281	95004	AFW	0595	1	1	1
71	281	95005	AFW	0595	1	1	1
72	285	87036	AFW	1187	1	4	4
73	285	90026	AFW	1190	1	2	2
74	285	92023	AFW	0792	1	4	4
75	285	93011	AFW	0693	1	2	2
76	285	93018	AFW	1293	1	2	2
77	285	94001	AFW	0294	1	4	4
78	286	87001	AFW	0187	1	4	4
79	286	88006	AFW	1088	1	8	8
80	286	89015	AFW	1089	1	9	8
81	286	90002	AFW	0290	1	4	4
82	286	90004	AFW	0690	1	8	8
83	286	91004	AFW	0391	1	8	8
84	286	92013	AFW	0992	1	4	4
85	286	92015	AFW	0992	1	4	4
86	286	95012	AFW	0695	1	4	4
87	287	91007	AFW	0791	1	4	4
88	287	92001	AFW	0192	1	4	4
89	287	92003	AFW	0692	1	4	4
90	287	93001	AFW	0193	1	4	4
91	287	94002	AFW	0894	1	4	4
92	287	94003	AFW	0894	1	4	4
93	289	88004	AFW	0888	1	4	4
94	289	89004	AFW	0889	1	1	1
95	289	91003	AFW	0991	1	1	1
96	289	91007	AFW	1191	1	4	4
97	289	92001	AFW	0192	1	1	1
98	295	87009	CVCS	0487	1	3	3
99	295	91008	AFW	0591	1	3	3
100	295	91016	CVCS	1191	1	3	3
101	295	92019	CVCS	1192	1	3	3
102	295	95022	CVCS	1195	1	3	3
103	305	87005	AFW	0487	1	2	2
104	305	87008	AFW	0687	1	2	2
105	305	87009	AFW	0787	1	2	2
106	305	88001	AFW	0388	1	2	2
107	305	88004	AFW	0488	1	2	2
108	305	88006	AFW	0588	1	2	2
109	305	88012	AFW	0988	1	2	2
110	305	89016	AFW	1289	1	2	2

APPENDIX IV - TABLE III (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1987-1995

<u>ITEM</u> <u>NO.</u>	<u>DKT</u> <u>NO.</u>	<u>LER</u> <u>NO.</u>	<u>PLANT</u> <u>SYSTEM</u>	<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>ESFs</u>	<u>NO.</u> <u>AOVs</u>	<u>NO. AOV</u> <u>DEMANDS</u>
111	305	91010	AFW	1091	1	2	2
112	305	92017	AFW	0992	1	2	2
113	305	93001	AFW	0193	1	2	2
114	305	93013	AFW	0693	1	2	2
115	309	89001	AFW	0189	1	9	9
116	309	94008	AFW	0594	1	9	9
117	311	88014	CVCS	0688	1	4	4
118	311	88024	AFW	1188	1	6	6
119	311	89005	CVCS	0389	1	4	4
120	311	90017	AFW	0590	1	1	1
121	311	90029	AFW	0690	1	10	10
122	311	90037	CVCS	0990	1	4	4
123	311	91009	AFW	0691	1	1	1
124	311	91012	AFW	0891	1	1	1
125	311	92001	AFW	0192	1	1	1
126	311	92014	AFW	0992	1	6	6
127	311	93002	AFW	0193	1	10	10
128	311	93005	AFW	0393	1	10	10
129	311	93009	AFW	0693	1	6	6
130	311	94008	AFW	0694	1	10	10
131	313	90017	RHR	1290	1	2	2
132	315	87008	AFW	0687	1	3	3
133	315	87021	AFW	1087	1	3	3
134	315	88001	AFW	0188	1	3	3
135	315	88011	AFW	1088	1	2	2
136	315	88013	AFW	1188	1	2	2
137	315	89001	AFW	0189	1	3	3
138	315	89003	AFW	0389	1	2	2
139	315	91004	AFW	0591	1	3	3
140	315	95003	AFW	0795	1	2	2
141	315	95005	AFW	0795	1	2	2
142	316	87004	AFW	0687	1	3	3
143	316	87005	AFW	0687	1	2	2
144	316	87007	AFW	0787	1	3	3
145	316	87008	AFW	0787	1	3	3
146	316	89014	AFW	0889	1	2	2
147	316	90004	AFW	0690	1	2	2
148	316	90012	AFW	1290	1	3	3
149	316	90013	AFW	1290	1	3	3
150	316	91004	AFW	0391	1	3	3
151	316	91006	AFW	0891	1	3	3
152	316	91010	AFW	1191	1	3	3
153	316	93007	AFW	0893	1	2	2
154	316	94001	AFW	0294	1	2	2
155	316	94005	AFW	0894	1	2	2
156	316	94008	AFW	1294	1	2	2
157	316	95005	AFW	0895	1	3	3
158	317	91003	AFW	1091	1	9	9
159	317	91008	AFW	1291	1	9	9
160	317	94001	AFW	0194	1	6	6
161	317	94006	AFW	0694	1	6	6
162	317	94007	AFW	0794	1	6	6
163	317	95002	AFW	0695	1	9	9
164	317	95005	AFW	1195	1	9	9
165	317	95006	AFW	1195	1	9	9

APPENDIX IV - TABLE III (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1987-1995

ITEM	DKT	LER	PLANT	EVENT	NO.	NO.	NO. AOV
<u>NO.</u>	<u>NO.</u>	<u>NO.</u>	<u>SYSTEM</u>	<u>DATE</u>	<u>ESFs</u>	<u>AOVs</u>	<u>DEMANDS</u>
166	318	87006	AFW	0987	1	6	6
167	318	87007	AFW	1087	1	6	6
168	318	87008	AFW	1187	1	9	9
169	318	88002	AFW	0188	1	12	12
170	318	88004	AFW	0488	1	12	12
171	318	93002	AFW	0693	1	6	6
172	318	94001	AFW	0194	1	9	9
173	318	95002	AFW	0195	1	9	9
174	327	88045	AFW	1188	1	5	5
175	327	88047	AFW	1288	1	5	5
176	327	89005	AFW	0289	1	5	5
177	327	89035	AFW	1289	1	4	4
178	327	90009	AFW	0590	1	5	5
179	327	90021	AFW	0990	1	4	4
180	327	90030	AFW	1190	1	5	5
181	327	92018	AFW	1092	1	4	4
182	327	92027	AFW	1292	1	5	5
183	327	94011	AFW	0794	1	5	5
184	327	94014	AFW	1194	1	5	5
185	327	95008	AFW	0695	1	5	5
186	328	88023	AFW	0588	1	9	9
187	328	88024	AFW	0588	1	12	12
188	328	88027	AFW	0688	1	12	12
189	328	88028	AFW	0688	1	12	12
190	328	89008	AFW	0789	1	12	12
191	328	90008	AFW	0490	1	6	6
192	328	91001	AFW	0191	1	12	12
193	328	81006	AFW	1191	1	12	12
194	328	95007	AFW	1295	1	6	6
195	334	88007	HPI	0688	1	1	1
196	334	98007	HPI	0589	1	1	1
197	334	93013	HPI	1093	1	1	1
198	334	94005	HPI	0691	1	1	1
199	334	95003	HPI	0295	1	1	1
200	348	87002	AFW	0187	1	3	3
201	348	87003	AFW	0187	1	3	3
202	348	87004	AFW	0187	1	3	3
203	348	87010	AFW	0587	1	3	3
204	348	88021	AFW	1088	1	3	3
205	348	89006	AFW	1189	1	3	3
206	348	90005	AFW	0790	1	3	3
207	348	91006	AFW	0591	1	3	3
208	348	91007	AFW	0691	1	3	3
209	348	91008	AFW	0891	1	3	3
210	348	91009	AFW	0891	1	3	3
211	348	91010	AFW	1091	1	3	3
212	348	92008	AFW	1292	1	3	3
213	348	95010	AFW	1195	1	3	3
214	364	87001	AFW	0287	1	4	4
215	364	89007	AFW	0589	1	4	4
216	364	89008	AFW	0589	1	4	4
217	364	89010	AFW	0989	1	4	4
218	364	89012	AFW	1089	1	4	4
219	364	89015	AFW	1189	1	4	4
220	364	91001	AFW	0491	1	4	4

APPENDIX IV - TABLE III (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1987-1995

ITEM	DKT	LER	PLANT	EVENT	NO.	NO.	NO. AOV
NO.	NO.	NO.	SYSTEM	DATE	ESFs	AOVs	DEMANDS
221	364	91002	AFW	0491	1	4	4
222	364	91004	AFW	0491	1	4	4
223	364	91005	AFW	0891	1	4	4
224	364	92001	AFW	0192	1	4	4
225	364	92002	AFW	0392	1	4	4
226	364	92003	AFW	0592	1	4	4
227	364	92005	AFW	0592	1	4	4
228	364	92006	AFW	0592	1	4	4
229	364	92007	AFW	0592	1	4	4
230	364	92008	AFW	1592	1	4	4
231	364	92010	AFW	1092	1	4	4
232	369	87017	CVCS	0887	1	5	5
233	369	88005	CVCS	0388	1	5	5
234	369	89004	CVCS	0389	1	5	5
235	369	91001	CVCS	0291	1	5	5
236	382	87008	AFW	0387	1	8	8
237	382	87012	AFW	0487	1	8	8
238	382	87016	AFW	0587	1	8	8
239	382	87029	AFW	0787	1	4	4
240	382	87028	AFW	1287	1	4	4
241	382	88016	AFW	0688	1	8	8
242	382	88033	AFW	1288	1	8	8
243	382	89013	AFW	0789	1	8	8
244	382	89024	AFW	1289	1	8	8
245	382	90002	AFW	0390	1	8	8
246	382	90003	AFW	0390	1	4	4
247	382	91013	AFW	0691	1	4	4
248	382	91019	AFW	0891	1	6	6
249	382	91022	AFW	1191	1	8	8
250	382	93001	AFW	0393	1	8	8
251	382	95002	AFW	0695	1	4	4
252	395	87015	AFW	0687	1	6	6
253	395	87021	AFW	0987	1	4	4
254	395	87027	AFW	1087	1	6	6
255	395	88002	AFW	0588	1	6	6
256	395	88006	AFW	0588	1	4	4
257	395	88007	AFW	0688	1	4	4
258	395	88009	AFW	0788	1	6	6
259	395	89020	AFW	1289	1	6	6
260	395	93001	AFW	0193	1	4	4
261	400	87008	AFW	0287	1	2	2
262	400	87012	AFW	0387	1	2	2
263	400	87013	AFW	0387	1	2	2
264	400	87014	AFW	0387	1	2	2
265	400	87017	AFW	0387	1	3	3
266	400	87018	AFW	0487	1	2	2
267	400	87019	AFW	0487	1	2	2
268	400	87024	AFW	0487	1	2	2
269	400	87025	AFW	0487	1	2	2
270	400	87026	AFW	0487	1	2	2
271	400	87028	AFW	0587	1	2	2
272	400	87031	AFW	0587	1	2	2
273	400	87035	AFW	0687	1	3	3
274	400	87029	AFW	0687	1	2	2
275	400	87037	AFW	0687	1	2	2

APPENDIX IV - TABLE III (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1987-1995

ITEM	DKT	LER	PLANT	EVENT	NO.	NO.	NO. AOV
<u>NO.</u>	<u>NO.</u>	<u>NO.</u>	<u>SYSTEM</u>	<u>DATE</u>	<u>ESFs</u>	<u>AOVs</u>	<u>DEMANDS</u>
276	400	87041	AFW	0887	1	2	2
277	400	87042	AFW	0787	1	3	3
278	400	87046	AFW	0787	1	2	2
279	400	87047	AFW	0887	1	2	2
280	400	87048	AFW	0987	1	2	2
281	400	87049	AFW	0987	1	2	2
282	400	87051	AFW	0887	1	2	2
283	400	87062	AFW	1187	1	3	3
284	400	87063	AFW	1187	1	2	2
285	400	88007	AFW	0388	1	2	2
286	400	88018	AFW	0788	1	2	2
287	400	88021	AFW	0888	1	2	2
288	400	88028	AFW	1088	1	2	2
289	400	89001	AFW	0189	1	3	3
290	400	89003	AFW	0289	1	3	3
291	400	89004	AFW	0289	1	2	2
292	400	89005	AFW	0289	1	3	3
293	400	89006	AFW	0389	1	2	2
294	400	89019	AFW	1289	1	3	3
295	400	89021	AFW	1289	1	3	3
296	400	91009	AFW	0591	1	2	2
297	400	91010	AFW	0691	1	3	3
298	400	91015	AFW	0591	1	2	2
299	400	92007	AFW	0792	1	2	2
300	400	92008	AFW	0792	1	2	2
301	400	92009	AFW	0792	1	3	3
302	400	92010	AFW	0792	1	2	2
303	400	93007	AFW	0593	1	3	3
304	400	95010	AFW	1095	1	2	2
305	412	87005	AFW	0787	1	8	8
306	412	87017	AFW	0887	1	3	3
307	412	87020	AFW	0987	1	8	8
308	412	87023	AFW	0987	1	8	8
309	412	87024	AFW	0987	1	3	3
310	412	87025	AFW	0987	1	3	3
311	412	87026	AFW	1087	1	8	8
312	412	87028	AFW	1087	1	8	8
313	412	87030	AFW	1987	1	3	3
314	412	87032	AFW	1087	1	8	8
315	412	87034	AFW	1987	1	3	3
316	412	87035	AFW	1187	1	8	8
317	412	88011	AFW	0888	1	3	3
318	412	89003	AFW	0189	1	8	8
319	412	89015	AFW	0589	1	3	3
320	412	89019	AFW	0689	1	8	8
321	412	89020	AFW	0689	1	3	3
322	412	90008	AFW	0790	1	8	8
323	412	91005	AFW	1191	1	8	8
324	412	92006	AFW	0592	1	3	3
325	412	92007	AFW	0592	1	3	3
326	412	92009	AFW	0692	1	3	3
327	412	93002	AFW	0193	1	8	8
328	412	94006	AFW	0694	1	2	2
329	412	95006	AFW	0895	1	8	8
330	413	87006	AFW	0187	1	2	2

APPENDIX IV - TABLE III (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1987-1995

<u>ITEM</u> <u>NO.</u>	<u>DKT</u> <u>NO.</u>	<u>LER</u> <u>NO.</u>	<u>PLANT</u> <u>SYSTEM</u>	<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>ESFs</u>	<u>NO.</u> <u>AOVs</u>	<u>NO. AOV</u> <u>DEMANDS</u>
331	413	87013	AFW	0387	1	2	2
332	413	87015	AFW	0487	1	2	2
333	413	87026	AFW	0787	1	2	2
334	413	87027	AFW	0787	1	2	2
335	413	87028	AFW	0787	1	2	2
336	413	87029	AFW	0787	1	2	2
337	413	88007	AFW	0188	1	2	2
338	413	88007	CVCS	0188	1	7	7
339	413	89008	AFW	0389	1	2	2
340	413	89008	CVCS	0389	1	7	7
341	413	89017	AFW	0689	1	2	2
342	413	89022	AFW	0889	1	2	2
343	413	91013	AFW	0691	1	2	2
344	413	91015	AFW	0791	1	2	2
345	413	91018	AFW	0991	1	2	2
346	413	91019	AFW	0991	1	2	2
347	413	92008	AFW	0792	1	2	2
348	413	93006	AFW	0693	1	2	2
349	413	93007	AFW	0393	1	2	2
350	413	93008	AFW	0793	1	2	2
351	413	94001	AFW	0194	1	2	2
352	414	87002	AFW	0187	1	4	4
353	414	87003	AFW	0187	1	4	4
354	414	87007	AFW	0287	1	4	4
355	414	87010	AFW	0387	1	4	4
356	414	87013	AFW	0387	1	2	2
357	414	87018	AFW	0587	1	4	4
358	414	87019	AFW	0587	1	4	4
359	414	87021	AFW	0787	1	2	2
360	414	87025	AFW	0987	1	4	4
361	414	87027	AFW	0987	1	4	4
362	414	87029	AFW	1187	1	2	2
363	414	88003	CVCS	0288	1	7	7
364	414	88005	AFW	0288	1	2	2
365	414	88007	AFW	0288	1	2	2
366	414	88012	AFW	0388	1	4	4
367	414	88014	AFW	0388	1	2	2
368	414	88019	AFW	0588	1	4	4
369	414	88020	AFW	0588	1	2	2
370	414	88021	AFW	0688	1	4	4
371	414	88023	AFW	0688	1	4	4
372	414	88025	AFW	0688	1	4	4
373	414	88028	AFW	0988	1	2	2
374	414	88031	AFW	1188	1	4	4
375	414	89001	AFW	0189	1	4	4
376	414	89002	AFW	0189	1	4	4
377	414	89003	AFW	0289	1	4	4
378	414	89003	CVCS	0289	1	7	7
379	414	89004	CVCS	0289	1	7	7
380	414	89015	AFW	0689	1	2	2
381	414	90013	AFW	1090	1	4	4
382	414	91006	AFW	0491	1	2	2
383	414	91008	AFW	0591	1	4	4
384	414	92001	AFW	0192	1	4	4
385	414	93003	AFW	0993	1	4	4

APPENDIX IV - TABLE III (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1987-1995

ITEM	DKT	LER	PLANT	EVENT	NO.	NO.	NO. AOV
NO.	NO.	NO.	SYSTEM	DATE	ESFs	AOVs	DEMANDS
386	414	94003	AFW	0794	1	2	2
387	414	94006	AFW	0994	1	4	4
388	414	94007	AFW	1094	1	4	4
389	414	95001	AFW	0295	1	4	4
390	414	95004	AFW	0495	1	4	4
391	414	95005	AFW	0595	1	2	2
392	424	88028	CVCS	1088	1	5	5
393	424	93006	CVCS	0493	1	5	5
394	424	94001	CVCS	0294	1	5	5
395	425	89006	CVCS	0389	1	5	5
396	443	87009	CVCS	0387	1	5	5
397	443	87012	CVCS	0487	1	5	5
398	443	87015	CVCS	0887	1	5	5
399	443	94001	CVCS	0194	1	5	5
400	445	90004	CVCS	0390	1	7	7
401	445	90017	AFW	0590	1	4	4
402	445	90020	AFW	0790	1	4	4
403	445	90020	CVCS	0790	1	7	7
404	445	90021	AFW	0790	1	4	4
405	445	90021	CVCS	0790	1	7	7
406	445	90025	AFW	0890	1	4	4
407	445	90027	AFW	0990	1	4	4
408	445	90029	AFW	0990	1	4	4
409	445	90030	AFW	0990	1	4	4
410	445	90037	CVCS	1190	1	7	7
411	445	91002	AFW	0191	1	4	4
412	445	91004	AFW	0291	1	4	4
413	445	91008	AFW	0391	1	4	4
414	445	91019	AFW	0691	1	4	4
415	445	91020	AFW	0791	1	4	4
416	445	91021	AFW	0791	1	4	4
417	445	91022	CVCS	0991	1	7	7
418	445	91023	AFW	1091	1	4	4
419	445	92001	AFW	0192	1	4	4
420	445	92009	AFW	0592	1	4	4
421	445	92014	AFW	0692	1	8	8
422	445	92016	AFW	0692	1	4	4
423	445	92016	CVCS	0692	1	7	7
424	445	92019	AFW	0792	1	4	4
425	445	92022	AFW	1092	1	4	4
426	445	95002	AFW	0595	1	4	4
427	445	95003	AFW	0695	1	8	8
428	445	95004	AFW	0695	1	8	8
429	445	95007	AFW	1195	1	4	4
430	482	87002	AFW	0187	1	3	3
431	482	87002	CVCS	0187	1	7	7
432	482	87004	AFW	0187	1	3	3
433	482	87005	AFW	0187	1	3	3
434	482	87017	AFW	0487	1	3	3
435	482	87022	AFW	0587	1	4	4
436	482	87027	AFW	0687	1	4	4
437	482	87030	AFW	0787	1	2	2
438	482	87037	AFW	0987	1	4	4
439	482	87041	AFW	0987	1	3	3
440	482	89002	AFW	0189	1	3	3

APPENDIX IV - TABLE III (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1987-1995

ITEM NO.	DKT NO.	LER NO.	PLANT SYSTEM	EVENT DATE	NO. ESFs	NO. AOVs	NO. AOV DEMANDS
441	482	89004	AFW	0289	1	3	3
442	482	90001	AFW	0290	1	3	3
443	482	90007	AFW	0590	1	3	3
444	482	90011	AFW	0590	1	3	3
445	482	90012	AFW	0590	1	3	3
446	482	90013	AFW	0590	1	3	3
447	482	90023	AFW	1090	1	4	4
448	482	90023	CVCS	1090	1	7	7
449	482	91006	AFW	0591	1	4	4
450	482	92002	AFW	0292	1	3	3
451	482	92016	AFW	1192	1	4	4
452	482	93009	CVCS	0593	1	7	7
453	482	94002	AFW	0194	1	3	3
454	482	95006	AFW	1195	1	3	3
455	483	87003	AFW	0487	1	3	3
456	483	87032	AFW	1187	1	3	3
457	483	88004	AFW	0288	1	3	3
458	483	88005	AFW	0488	1	3	3
459	483	88006	AFW	0488	1	3	3
460	483	88007	AFW	0588	1	3	3
461	483	88010	AFW	0988	1	3	3
462	483	89003	AFW	0389	1	3	3
463	483	89005	AFW	0589	1	3	3
464	483	89006	AFW	0589	1	3	3
465	483	90005	AFW	0590	1	3	3
466	483	90007	AFW	0690	1	3	3
467	483	90015	AFW	1190	1	4	4
468	483	90016	AFW	1190	1	3	3
470	483	90017	AFW	1290	1	3	3
471	483	91006	AFW	1191	1	3	3
472	483	92002	AFW	0192	1	3	3
473	483	92003	AFW	0192	1	3	3
474	483	92004	AFW	0392	1	3	3
475	483	92006	AFW	0592	1	3	3
476	483	92010	AFW	0992	1	3	3
477	483	95005	AFW	0895	1	3	3
478	483	95006	AFW	1095	1	3	3

APPENDIX IV - TABLE IIIA
PWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1996-1998

<u>ITEM</u> <u>NO.</u>	<u>DKT</u> <u>NO.</u>	<u>LER</u> <u>NO.</u>	<u>PLANT</u> <u>SYSTEM</u>	<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>ESFs</u>	<u>NO.</u> <u>AOVs</u>	<u>NO. AOV</u> <u>DEMANDS</u>
1	247	96003	AFW	0396	1	8	8
2	247	97001	AFW	0197	1	4	4
3	247	97018	AFW	0797	1	6	6
4	255	98010	AFW	0798	1	3	3
5	269	96004	AFW	0296	1	4	4
6	269	97008	AFW	0797	1	4	4
7	270	98003	HPI	0698	1	1	1
8	270	98007	AFW	1198	1	4	4
9	272	98006	AFW	0298	1	6	6
10	280	98014	AFW	1198	1	2	2
11	281	97001	AFW	0297	1	2	2
12	286	97023	AFW	0997	1	8	8
13	286	97025	AFW	0997	1	8	8
14	286	98006	AFW	0898	1	8	8
15	287	96001	AFW	0396	1	4	4
16	289	97007	AFW	0697	1	5	5
17	305	96003	AFW	0496	1	2	2
18	305	98005	AFW	0298	1	2	2
19	311	97014	AFW	1097	1	6	6
20	315	96002	AFW	0396	1	3	3
21	315	98040	RHR	0898	1	1	1
22	316	96005	AFW	0596	1	2	2
23	316	97001	AFW	0397	1	3	3
24	317	97009	AFW	0996	1	6	6
25	318	96005	AFW	1196	1	8	8
26	327	96010	AFW	1196	1	5	5
27	327	97012	AFW	0897	1	5	5
28	327	98001	AFW	0598	1	5	5
29	327	98003	AFW	1198	1	4	4
30	328	96005	AFW	1096	1	8	8
31	328	96006	AFW	1296	1	8	8
32	328	98001	AFW	0898	1	8	8
33	328	98002	AFW	1098	1	8	8
34	370	97001	CVCS	0597	1	5	5
35	382	96006	AFW	0596	1	8	8
36	382	98014	AFW	0798	1	8	8
37	395	97002	AFW	0497	1	6	6
38	400	96008	AFW	0496	1	3	3
39	400	96018	AFW	0996	1	3	3
40	400	97001	AFW	0197	1	3	3
41	400	97014	RHR	0597	1	2	2
42	400	97016	AFW	0697	1	2	2
43	400	97019	AFW	0797	1	3	3
44	400	98007	AFW	1098	1	3	3
45	413	96005	AFW	0696	1	4	4
46	413	97011	CVCS	1297	1	7	7
47	414	96001	AFW	0296	1	4	4
48	414	96001	CVCS	0296	1	7	7
49	414	97006	AFW	0797	1	4	4
50	445	96001	CVCS	0196	1	7	7
51	482	96006	AFW	0696	1	4	4
52	483	96003	AFW	1096	1	4	4
53	483	96005	AFW	1196	1	4	4
54	483	96006	AFW	1296	1	4	4

APPENDIX IV - TABLE IV
BWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1987-1995

<u>ITEM</u> <u>NO.</u>	<u>DKT</u> <u>NO.</u>	<u>LER</u> <u>NO.</u>	<u>PLANT</u> <u>SYSTEM</u>	<u>EVENT</u> <u>DATE</u>	<u>NO.</u> <u>ESFs</u>	<u>NO.</u> <u>AOVs</u>	<u>NO. AOV</u> <u>DEMANDS</u>
1	219	88002	LPCS	1088	1	4	4
2	219	91005	LPCS	0491	1	4	4
3	219	93008	LPCS	1293	1	4	4
4	237	89005	LPCS	0289	1	2	2
5	237	94012	LPCS	0494	1	2	2
6	260	88017	LPCS	1288	1	6	6
7	260	90005	HPCI	0590	1	2	2
8	260	94004	HPCI	0494	1	2	2
9	263	87003	RCIC	0487	1	2	2
10	263	87009	HPCI	0487	1	1	1
11	263	91009	HPCI	0491	1	1	1
12	263	91019	RCIC	0891	1	1	1
13	265	87013	HPCI	1087	1	1	1
14	265	87017	HPCI	1187	1	1	1
15	265	88027	HPCI	1188	1	1	1
16	277	89012	RCIC	0589	1	1	1
17	277	89033	RCIC	1289	1	1	1
18	277	92010	RCIC	0792	1	1	1
19	277	93004	RCIC	0393	1	1	1
20	293	91024	RCIC	1091	1	1	1
21	293	93004	RCIC	0893	1	1	1
22	293	93022	RCIC	0993	1	1	1
23	298	87003	HPCI	0187	1	1	1
24	298	87009	HPCI	0287	1	1	1
25	298	88021	HPCI	0888	1	1	1
26	298	89026	HPCI	1189	1	1	1
27	298	90011	HPCI	1090	1	1	1
28	298	93038	HPCI	1293	1	1	1
29	298	94004	HPCI	0394	1	1	1
30	321	94002	LPCS	0394	1	2	2
31	341	88004	HPCI	0188	1	1	1
32	341	88022	LPCS	0688	1	2	2
33	341	92012	HPCI	1192	1	1	1
34	341	93010	HPCI	0893	1	1	1
35	341	95004	HPCI	0495	1	1	1
36	352	87019	LPCS	0587	1	2	2
37	352	90025	LPCS	1190	1	2	2
38	353	93003	LPCS	0293	1	2	2
39	353	95006	LPCS	0395	1	2	2
40	353	95010	LPCS	0895	1	2	2
41	354	92004	LPCS	0392	1	6	6
42	366	92023	LPCS	1192	1	2	2
43	373	92003	RCIC	0392	1	1	1
44	373	92008	RCIC	0692	1	1	1
45	373	93015	RCIC	0993	1	1	1
46	373	93015	LPCS	0993	1	1	1
47	374	92005	RCIC	0392	1	2	2
48	374	92012	RCIC	0892	1	2	2
49	374	92013	RCIC	0992	1	2	2
50	374	92016	RCIC	1192	1	2	2
51	374	94008	RCIC	1094	1	2	2
52	374	94010	RCIC	1294	1	2	2
53	374	95001	RCIC	0195	1	2	2
54	374	95001	LPCS	0195	1	1	1
55	387	87013	RCIC	0487	1	1	1

APPENDIX IV - TABLE IV (CONTINUED)
BWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1987-1995

ITEM	DKT	LER	PLANT	EVENT	NO.	NO.	NO. AOV
NO.	NO.	NO.	SYSTEM	DATE	ESFs	AOVs	DEMANDS
56	387	91008	RCIC	0791	1	1	1
57	387	91008	HPCI	0791	1	2	2
58	388	87006	RCIC	0487	1	1	1
59	388	87006	HPCI	0487	1	2	2
60	397	87002	RCIC	0387	1	1	1
61	397	88003	RCIC	0288	1	1	1
62	397	89002	RCIC	0189	1	1	1
63	397	91032	RCIC	1191	1	1	1
64	397	93027	RCIC	0893	1	1	1
65	397	94014	LPCS	0794	1	1	1
66	397	95002	RCIC	0295	1	1	1

APPENDIX IV - TABLE IVA
BWR APPLICATION CODED AOV ASSEMBLIES - SELECTED RI SYSTEM DATA SOURCE INPUTS
ESF DEMANDS 1996-1998

ITEM	DKT	LER	PLANT	EVENT	NO.	NO.	NO. AOV
NO.	NO.	NO.	SYSTEM	DATE	ESFs	AOVs	DEMANDS
1	260	97001	RCIC	0497	1	2	2
2	260	97001	HPCI	0497	1	2	2
3	265	97001	HPCI	0297	1	1	1
4	296	96002	RCIC	0496	1	2	2
5	296	96002	HPCI	0496	1	2	2
6	296	96003	RCIC	0596	1	2	2
7	296	96003	HPCI	0596	1	2	2
8	388	96004	RCIC	0796	1	1	1
9	388	96004	HPCI	0796	1	2	2
10	397	98002	RCIC	0398	1	1	1
11	397	98003	RCIC	0398	1	1	1
12	397	99007	LPCS	0598	1	1	1

APPENDIX IV - TABLE V
PWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ./YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
1	2	CVCS	6	0.67	4	9	36
2	2	RCS	2				
3	2	CCW	6	0.67	4	9	36
4	6	CVCS	7	0.67	4.67	9	42
5	6	RCS	2				
6	6	RHR	1	4	4	9	36
7	6	CCW	1	0.67	0.67	9	6
8	8	AFW	8	4	32	9	288
9	8	CVCS	2	0.67	1.33	9	12
10	8	RCS	2				
11	8	RHR	1	4	4	9	36
12	8	CCW	3	0.67	2	9	18
13	10	AFW	6	4	24	9	216
14	10	CVCS	4	0.67	2.67	9	24
15	10	RCS	2				
16	11	AFW	6	4	24	9	216
17	11	CVCS	4	0.67	2.67	9	24
18	11	RCS	2				
19A	13	AFW	5	4	20	9	
19B	13	AFW	2	0.67	1.33	9	192
20A	13	CVCS	7	4	28	9	
20B	13	CVCS	11	0.67	7.33	9	318
21	13	RCS	2				
22A	13	RHR	5	4	20	9	
22B	13	RHR	2	0.67	1.33	9	192
23	13	HPI	4	0.67	2.67	9	24
24	13	CCW	3	0.67	2	9	18
25	16	RCS	2				
26A	19	CVCS	2	4	8	9	

APPENDIX IV - TABLE V (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ./YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
26B	19	CVCS	7	0.67	4.67	9	114
27	19	RCS	2				
28	19	HPI	4	0.67	2.67	9	24
29	19	CCW	1	0.67	0.67	9	6
30A	20	AFW	2	4	8	9	
30B	20	AFW	2	0.67	1.33	9	84
31A	20	CVCS	2	4	8	9	
31B	20	CVCS	3	0.67	2	9	90
32	20	HPI	1	4	4	9	36
33	20	CCW	1	0.67	0.67	9	6
34A	21	AFW	2	4	8	9	
34B	21	AFW	2	0.67	1.33	9	84
35A	21	CVCS	2	4	8	9	
35B	21	CVCS	3	0.67	2	9	90
36	21	HPI	1	4	4	9	36
37	21	CCW	1	0.67	0.67	9	6
38A	23	AFW	8	4	32	9	
38B	23	AFW	5	0.67	3.33	9	318
39A	23	CVCS	6	4	24	9	
39B	23	CVCS	12	0.67	8	9	288
40	23	RCS	2				
41	23	RHR	2	4	8	9	72
42	23	HPI	3	0.67	2	9	19
43	23	CCW	2	0.67	1.33	9	12
44	24	RCS	2				
45	27	AFW	6	4	24	9	
46	27	AFW	2	0.67	1.33	9	228
47A	27	CVCS	7	4	28	9	
47B	27	CVCS	6	0.67	4	9	288

APPENDIX IV - TABLE V (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ./YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
48	27	RCS	2				
49	27	RHR	3	0.67	2	9	18
50	28	AFW	1	4	4	9	36
51A	28	CVCS	7	4	28	9	
51B	28	CVCS	2	0.67	1.33	9	264
52	28	RCS	2				
53	28	RHR	3	0.67	2	9	18
54	28	CCW	4	0.67	2.67	9	24
55	29	CVCS	3	0.67	2	9	18
56	29	RCS	2				
57	29	RHR	1	4	4	9	36
58	30	AFW	4	4	16	9	144
59	30	RCS	2				
60	30	CCW	4	0.67	2.67	9	24
61	31	AFW	8	4	32	9	288
62	31	CVCS	2	0.67	1.33	9	12
63	31	RCS	2				
64	31	RHR	1	4	4	9	36
65	31	CCW	1	0.67	0.67	9	6
66A	32	AFW	2	4	8	9	
66B	32	AFW	2	0.67	1.33	9	84
67A	32	CVCS	2	4	8	9	
67B	32	CVCS	3	0.67	2	9	90
68	32	RHR	2	4	8	9	72
69	32	CCW	1	0.67	0.67	9	6
70A	33	AFW	4	4	16	9	
70B	33	AFW	1	0.67	0.67	9	150
71A	33	CVCS	4	4	16	9	
71B	33	CVCS	3	0.67	2	9	162

APPENDIX IV - TABLE V (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ./YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
72	33	CCW	1	0.67	0.67	9	6
73	35	AFW	1	4	4	9	36
74A	35	CVCS	3	4	12	9	
74B	35	CVCS	5	0.67	3.33	9	138
75	35	RCS	2				
76	35	CCW	1	0.67	0.67	9	6
77A	38	CVCS	3	4	12	9	
77B	38	CVCS	8	0.67	5.33	9	156
78	38	RCS	2				
79	38	HPI	4	0.67	2.67	9	24
80	38	CCW	1	0.67	0.67	9	6
81A	39	CVCS	2	4	8	9	
81B	39	CVCS	4	0.67	2.67	9	96
82	39	RHR	1	4	4	9	36
83	39	HPI	4	0.67	2.67	9	24
84	39	CCW	18	0.67	12	9	108
85	40	AFW	1	4	4	9	36
86A	40	CVCS	5	4	20	9	
86B	40	CVCS	6	0.67	4	9	216
87	40	RCS	3				
88	40	HPI	1	0.67	0.67	9	6
89	40	CCW	1	0.67	0.67	9	6
90	41	AFW	2	4	8	9	72
91	41	RCS	2				
92	42	CVCS	1	0.67	0.67	9	6
93	42	RCS	2				
94	43	AFW	9	4	36	9	324
95A	43	CVCS	2	4	8	9	
95B	43	CVCS	11	0.67	7.33	9	138

APPENDIX IV - TABLE V (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ/YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
96	43	RCS	2				
97	43	RHR	2	4	8	9	72
98	43	CCW	8	0.67	5.33	9	48
99A	44	AFW	8	4	32	9	
99B	44	AFW	5	0.67	3.33	9	318
100A	44	CVCS	6	4	24	9	
100B	44	CVCS	12	0.67	8	9	288
101	44	RCS	2				
102	44	RHR	2	4	8	9	72
103	44	HPI	3	0.67	2	9	18
104	44	CCW	2	0.67	1.33	9	12
105	45	CVCS	2	0.67	1.33	9	12
106	45	RHR	2	4	8	9	72
107	45	CCW	3	0.67	2	9	18
108	46	AFW	3	0.67	2	9	18
109A	46	CVCS	7	4	28	9	
109B	46	CVCS	10	0.67	6.67	9	317
110	46	RCS	2				
111	46	RHR	1	4	4	9	36
112	46	CCW	5	0.67	3.33	9	30
113	47	AFW	3	0.67	2	9	18
114A	47	CVCS	7	4	28	9	
114B	47	CVCS	10	0.67	6.67	9	312
115	47	RCS	2				
116	47	RHR	1	4	4	9	36
117	47	CCW	7	0.67	4.67	9	42
118	48	AFW	12	4	48	9	432
119A	48	CVCS	5	4	20	9	
119B	48	CVCS	11	0.67	7.33	9	246

APPENDIX IV - TABLE V (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ./YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
120	48	RCS	2				
121	48	RHR	1	4	4	9	36
122	48	CCW	4	0.67	2.67	9	24
123	49	AFW	12	4	48	9	432
124A	49	CVCS	5	4	20	9	
124B	49	CVCS	11	0.67	7.33	9	246
125	49	RCS	2				
126	49	RHR	1	4	4	9	36
127	49	CCW	4	0.67	2.67	9	24
128	51	RCS	2				
129	54	AFW	5	4	20	9	180
130	54	CVCS	4	0.67	2.67	9	24
131	54	RCS	2				
132	54	RHR	1	4	4	9	36
133	54	HPI	3	0.67	2	9	18
134	54	CCW	1	0.67	0.67	9	6
135	55	AFW	8	4	32	9	288
136	55	CVCS	4	0.67	2.67	9	24
137	55	RCS	2				
138	55	RHR	1	4	4	9	36
139	55	HPI	3	0.67	2	9	18
140	55	CCW	1	0.67	0.67	9	6
141	58	RCS	2				
142	58	HPI	1	4	4	9	36
143	59	CVCS	2	4	8	9	72
144	59	RCS	2				
145	59	CCW	2	0.67	1.33	9	12
146	60	AFW	2	4	8	9	72
147	60	RCS	2				

APPENDIX IV - TABLE V (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ./YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
148	61	CVCS	3	0.67	2	9	18
149	61	RCS	2				
150	61	RHR	3	0.67	2	9	18
151	61	CCW	19	0.67	12.67	9	114
152	62	CVCS	2	0.67	1.33	9	12
153	62	RCS	2				
154	62	RHR	3	0.67	2	9	18
155	62	CCW	13	0.67	8.67	9	78
156A	65	CVCS	6	4	24	9	
156B	65	CVCS	8	0.67	5.33	9	264
157	65	RHR	2	4	8	9	72
158	66	AFW	3	4	12	9	108
159	66	CVCS	3	0.67	2	9	18
160	66	RCS	2				
161	70	RCS	2				
162	71	RCS	2				
163	72	AFW	4	4	16	9	144
164	72	CVCS	4	0.67	2.67	9	24
165	72	RCS	2				
166	74	CVCS	6	0.67	4	9	36
167	74	RHR	1	0.67	0.67	9	6
168A	75	CVCS	5	4	20	9	
168B	75	CVCS	9	0.67	6	9	234
169	75	RCS	2				
170	75	RHR	3	4	12	9	108
171	75	HPI	2	0.67	1.33	9	12
172A	76	CVCS	3	4	12	9	
172B	76	CVCS	11	0.67	7.33	9	174
173	76	RCS	2				

APPENDIX IV - TABLE V (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ./YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
174	76	RHR	3	4	12	9	108
175	76	HPI	3	0.67	2	9	18
176	79	AFW	8	4	32	9	288
177	79	CVCS	2	4	8	9	72
178	79	RCS	2				
179	79	RHR	2	4	8	9	72
180	79	CCW	3	0.67	2	9	18
181	82	RCS	2				
182	82	CCW	4	0.67	2.67	9	24
183	83	AFW	6	4	24	9	216
184	83	CVCS	10	0.67	6.67	9	60
185	83	RCS	2				
186	83	RHR	8	4	32	9	288
187	85	AFW	3	4	12	8.7	104
188A	85	CVCS	8	4	32	8.7	
188B	85	CVCS	9	0.67	6	8.7	331
189	85	RCS	2				
190	85	RHR	6	4	24	8.7	209
191A	87	AFW	6	4	24	8.2	
191B	87	AFW	2	0.67	1.33	8.2	208
192	87	RCS	2				
193	88	AFW	4	4	16	9	144
194A	88	CVCS	7	4	28	9	
194B	88	CVCS	6	0.67	4	9	288
195	88	RCS	2				
196	88	RHR	2	4	8	9	72
197	89	AFW	4	4	16	9	144
198A	89	CVCS	7	4	28	9	
198B	89	CVCS	6	0.67	4	9	288

APPENDIX IV - TABLE V (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

TEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ/YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
199	89	RCS	2				
200	89	RHR	2	4	8	9	72
201	91	RCS	2				
202	91	RHR	4	4	16	9	144
203	91	HPI	7	0.67	4.67	9	42
204A	92	CVCS	5	4	20	8.6	
204B	92	CVCS	5	0.67	3.33	8.6	175
205	92	AFW	2	4	8	8.6	69
206	92	RHR	2	4	8	8.6	69
207A	93	CVCS	5	4	20	6.6	
207B	93	CVCS	5	0.67	3.33	6.6	154
208	93	RCS	2				
209	93	RHR	2	4	8	6.6	53
210A	95	CVCS	5	4	20	5.3	
210B	95	CVCS	5	0.67	3.33	5.3	124
211	95	RCS	2				
212	95	RHR	2	4	8	5.3	42
213	95	CCW	10	0.67	6.67	5.3	35
214A	96	AFW	8	4	32	5.3	
214B	96	AFW	2	0.67	1.33	5.3	177
215A	96	CVCS	7	4	28	5.3	
215B	96	CVCS	7	0.67	4.67	5.3	173
216	96	RCS	2				
217	96	RHR	6	4	24	5.3	127
218	96	CCW	2	0.67	1.33	5.3	7
219	97	CVCS	1	0.67	0.67	9	6
220	97	RCS	2				
221	97	HPI	4	0.67	2.67	9	24
222	98	CVCS	1	0.67	0.67	8.3	6

APPENDIX IV - TABLE V (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ./YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
223	98	RCS	2				
224	98	HPI	4	0.67	2.67	8.3	22
225	99	CVCS	1	0.67	0.67	7.7	5
226	99	RCS	2				
227	99	HPI	2	0.67	1.33	7.7	10
228	99	CCW	2	0.67	1.33	7.7	10
229	100	CVCS	1	0.67	0.67	7.2	5
230	100	RCS	2				
223	100	HPI	2	0.67	1.33	7.2	10
224	100	CCW	2	0.67	1.33	7.2	10
225	103	AFW	4	4	16	9	144
226A	103	CVCS	9	4	36	9	
226B	103	CVCS	10	0.67	6.67	9	384
227	103	RCS	2				
228	103	RHR	2	4	8	9	72
229	103	CCW	2	0.67	1.33	9	12
230	104	AFW	4	4	16	9	144
231	104	CVCS	1	0.67	0.67	9	12
232	104	RCS	2				
233	104	RHR	2	4	8	9	72
234	104	HPI	2	0.67	1.33	9	12
235	105	RCS	2				
236	105	RHR	3	4	12	6.5	78
237	105	CCW	1	0.67	0.67	6.5	4
238	106	RCS	2				
239	106	RHR	3	4	12	7.7	92
240	106	CCW	1	0.67	0.67	7.7	5
241A	107	CVCS	4	4	16	9	
241B	107	CVCS	10	0.67	6.67	9	204

APPENDIX IV - TABLE V (CONTINUED)
PWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ./YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
242	107	RCS	2				
243	107	RHR	1	4	4	9	36
244A	108	CVCS	4	4	16	9	
244B	108	CVCS	10	0.67	6.67	9	204
245	108	RCS	2				
246	108	RHR	1	4	4	9	36
247A	109	CVCS	4	4	16	8	
247B	109	CVCS	10	0.67	6.67	8	181
248	109	RCS	2				
249	109	RHR	1	4	4	8	32

Note: The RCS system data is provided for the number of application coded pressurizer spray AOVs only.

APPENDIX IV - TABLE VI
BWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ./YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
1	3	LPCS	4	4	16	9	144
2	4	LPCS	2	0.67	1.33	9	12
3	5	LPCS	2	4	8	9	72
4	9	LPCS	2	4	8	9	72
5	12	HPCI	1	4	4	9	36
6	12	LPCS	2	4	8	9	72
7A	14	RCIC	1	4	4	9	
7B	14	RCIC	1	0.67	0.67	9	42
8A	14	HPCI	1	4	4	9	
8B	14	HPCI	1	0.67	0.67	9	42
9A	14	LPCS	2	4	8	9	
9B	14	LPCS	4	0.67	2.67	9	96
10A	15	RCIC	1	4	4	9	
10B	15	RCIC	1	0.67	0.67	9	42
11A	15	HPCI	1	4	4	9	
11B	15	HPCI	1	0.67	0.67	9	42
12A	15	LPCS	2	4	8	9	
12B	15	LPCS	4	0.67	2.67	9	96
13A	17	RCIC	1	4	4	9	
13B	17	RCIC	1	0.67	0.67	9	42
14A	17	HPCI	1	4	4	9	
14B	17	HPCI	1	0.67	0.67	9	42
15	17	LPCS	2	4	8	9	72
16	18	HPCI	1	4	4	9	36
17	18	LPCS	2	4	8	9	72
18	25	RCIC	1	4	4	9	36
19	25	HPCI	1	4	4	9	36
20	26	RCIC	1	4	4	9	36
21	26	HPCI	1	4	4	9	36

APPENDIX IV - TABLE VI (CONTINUED)
BWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ./YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
22	34	RCIC	1	4	4	9	36
23A	36	RCIC	1	4	4	9	
23B	36	RCIC	1	0.67	0.67	9	42
24A	36	HPCI	1	4	4	9	
24B	36	HPCI	1	0.67	0.67	9	42
25A	36	LPCS	2	4	8	9	
25B	36	LPCS	4	0.67	2.67	9	96
27	37	HPCI	1	0.67	0.67	9	6
28	50	LPCS	2	4	8	9	72
29A	57	LPCS	2	4	8	9	
29B	57	LPCS	2	0.67	1.33	9	84
30	63	HPCI	1	4	4	8	32
31	63	LPCS	2	4	8	8	64
32	67	LPCS	2	4	8	9	72
33	68	LPCS	2	4	8	5.9	47
34A	69	LPCS	2	4	8	9	
35B	69	LPCS	4	0.67	2.67	9	96
36	73	LPCS	2	4	8	9	72
37	77	RCIC	1	4	4	9	36
38	77	LPCS	1	4	4	9	36
39	78	RCIC	2	4	8	9	72
40	78	LPCS	1	4	4	9	36
41	80	RCIC	1	0.67	0.67	9	6
42	80	HPCI	2	0.67	1.33	9	12
43A	80	LPCS	2	4	8	9	
43B	80	LPCS	4	0.67	2.67	9	96
44	81	RCIC	1	4	4	9	36
45	81	HPCI	2	0.67	1.33	9	12
46A	81	LPCS	2	4	8	9	

APPENDIX IV - TABLE VI (CONTINUED)
BWR APPLICATION CODED AOV ASSEMBLY - SELECTED SYSTEM DATA SOURCE INPUTS
ESTIMATED SURVEILLANCE TEST DEMANDS - 1987-1995

ITEM NUMBER	PLANT ID NUMBER	PLANT SYSTEM	NO. AOVs/ SYSTEM	SURV TST FREQ./YR	DEMAND/ YEAR	NO. YRS/ PERIOD	SYS TOT AOV-DEM
46B	81	LPCS	4	0.67	2.67	9	96
47	84	RCIC	1	4	4	9	36
48	84	LPCS	1	4	4	9	36
49	86	LPCS	1	4	4	7.7	31
50	90	LPCS	1	4	4	9	36
51	102	LPCS	1	4	4	8.1	32

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11. ABSTRACT (200 words or less)

This report documents an analysis of the performance of safety-related air-operated valve assemblies (valve body and pneumatic operator subcomponents) used in pressurized water reactors (PWRs) and boiling water reactors (BWRs) in U.S. commercial power reactor plants.

A risk-based analysis of operating data and an engineering analysis of trends and patterns was performed to provide insights into the performance of air-operated valve components on an industry basis and comparison of results with data used by plant-specific probabilistic risk assessments. The data used in this report was from the 1992-1995 period for engineering analysis of risk-important systems. Failure probability estimates used combined engineering safety features data (1987-1998) and surveillance test data (1987-1995).

12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.)

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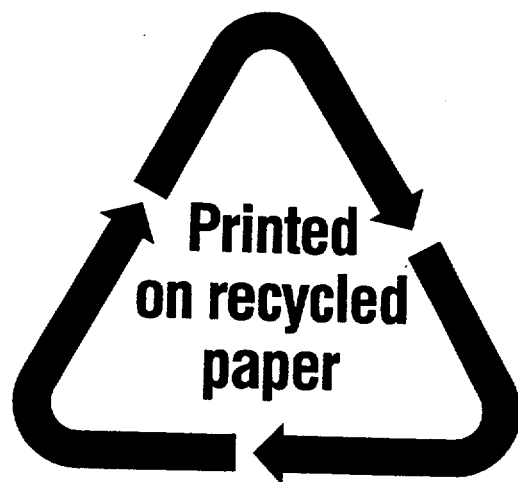
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